Technical Report REMR-CS-51
December 1996

US Army Corps of Engineers
Waterways Experiment Station

Repair, Evaluation, Maintenance, and Rehabilitation Research Program

A Constructibility Demonstration of Geomembrane Systems Installed Underwater on Concrete Hydraulic Structures

by Matthew A. Marcy
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CARPI U.S.A., Inc.

Prepared for Headquarters, U.S. Army Corps of Engineers

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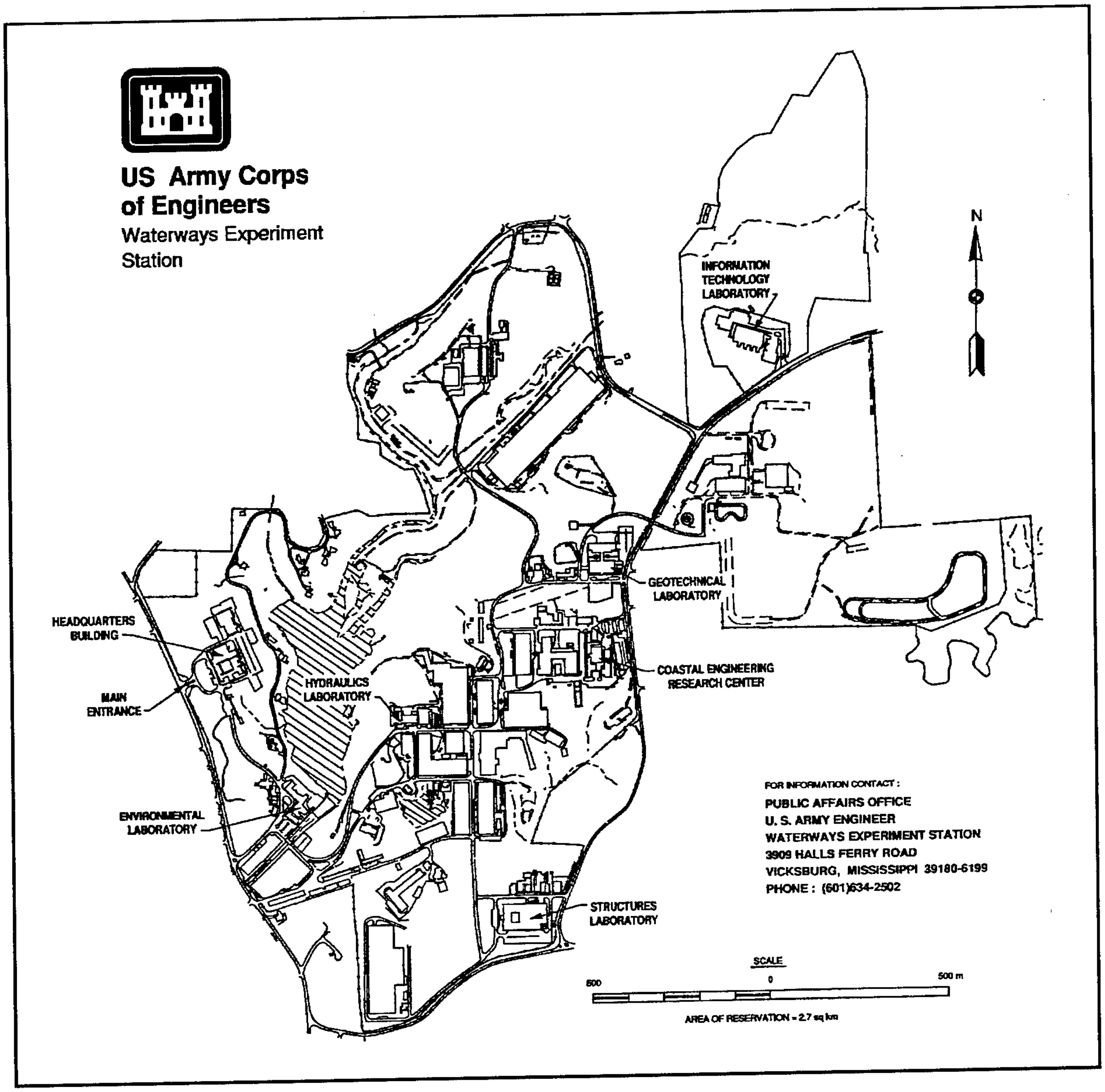

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Preface

The study reported herein was authorized by Headquarters, U.S. Army Corps of Engineers (HQUSACE), under Civil Works Research Work Unit 32636, "New Concepts in Maintenance and Repair of Concrete Structures," for which Mr. James E. McDonald, Structures Laboratory (SL), U.S. Army Engineer Waterways Experiment Station (WES), is the Principal Investigator. This work unit is part of the Concrete and Steel Structures Problem Area of the Repair, Evaluation, Maintenance, and Rehabilitation (REMR) Research Program.

The REMR Technical Monitor is Mr. M. K. Lee, HQUSACE. Dr. Tony C. Liu (CERD-C) is the REMR Coordinator at the Directorate of Research and Development, HQUSACE. Mr. Harold C. Tohlen (CECW-O) and Dr. Liu serve as the REMR Overview Committee. Mr. William F. McCleese, WES, is the REMR Program Manager. Mr. McDonald is the Problem Area Leader for Concrete and Steel Structures.

The study was performed by Oceaneering International, Inc., and CARPI, U.S.A., Inc., formerly Sibelon U.S.A., under contract to WES. The work was conducted under the general supervision at WES of Mr. Bryant Mather, Director, SL, and Mr. McCleese, and under the direct supervision of Mr. McDonald. This report was prepared by Mr. Matthew A. Marcy, Oceaneering International, Inc., and Dr. Alberto M. Scuero and Dr. Gabriella Vaschetti, CARPI U.S.A., Inc.

At the time of publication of this report, Director of WES was Dr. Robert W. Whalin. Commander was COL Bruce K. Howard, EN.

Conversion Factors, Non-SI to SI Units of Measurement

Non-SI units of measurement used in this report can be converted to SI (metric) units as follows:

Multiply	By	To Obtain
cubic feet	0.092903	cubic metres
feet	0.3048	metres
foot pounds (force)	1.355818	joule
inches	25.4	millimetres
pounds (force)	4.448222	newtons
pounds (force) per square foot	0.082737084	megapascals
pounds (force) per square inch	0.006894757	megapascals
square foot	0.09290304	square metres
ton (force)	8896.44	newtons
To obtain Celsius (C) temperature readings from Fahrenheit (F) readings, use the following formula: C = (5/9) (F - 32). To obtain Kelvin (K) readings, use K = (5/9) (F - 32) + 273.15.		

1 Introduction

A research program was initiated by the U. S. Army Engineer Waterways Experiment Station to develop a procedure for the underwater installation of a membrane system to minimize or eliminate water intrusion in a distressed or deteriorated concrete hydraulic structure. Such a procedure would significantly increase potential applications of the membrane system, because it would eliminate the need for dewatering of the structure prior to repair.

The program was designed to be conducted in three phases:

Phase I: Conduct research, material testing, and detailed evaluation of individual components and techniques resulting in the design of one or more systems for the proposed underwater installation.

Phase II: Demonstrate the constructibility of the system designed in Phase I through the underwater installation of a membrane system on a concrete test structure located in a suitable controlled environment.

Phase III: Confirm the applicability of the selected system in the field through a full-scale underwater installation on an existing concrete structure to be designated and provided by the U. S. Army Corps of Engineers.

Phase I of the program was completed by Oceaneering and CARPI U.S.A. resulting in a conceptual design. The results of Phase I are documented in Technical Report REMR-CS-50.[1]

In this report, it was concluded that a system which has proven successful when installed in the dry, SIBELON SYSTEMS, could be adapted for underwater installation. Applicability of the conceptual design was evaluated for a variety of scenarios. These scenarios included the size of the repair area, the use of a drainage system, and fluctuation of the water level. This exercise reinforced the

[1] Christensen, J. Chris, Marcy, Matthew, Scuero, Alberto, and Vaschetti, Gabriella. (1995). "A Conceptual Design for Underwater Installation of Geomembrane Systems on Concrete Hydraulic Structures," Technical Report REMR-CS-50, U. S. Army Engineer Waterways Experiment Station, Vicksburg, MS.

need to consider site specific conditions when preparing specifications for an actual repair.

After completing the conceptual design, the project proceeded to Phase II, a constructibility demonstration of the system, which is reported herein.

Objective

The objective of Phase II was to demonstrate that the conceptual system designed in Phase I can be practically installed underwater and that it provides a reliable barrier to water intrusion.

2 Description of Study

The constructibility demonstration was accomplished by a multidisciplined research team consisting of the following individuals listed in Table 1:

Table 1
Research Team

Team Member	Company	Area of Expertise
Jon Campbell	Oceaneering	Commercial Diving
Piero Comazzi	CARPI U.S.A.	Geosynthetics Installation
Ezio L. Laveriotti	CARPI U.S.A.	Technical Study & Design of Geosynthetic Applications
Matthew A. Marcy	Oceaneering	Civil Engineering/Commercial Diving
Paola Ravaldini	CARPI U.S.A.	Membrane Testing
Walter Scott	Oceaneering	Commercial Diving
Alberto M. Scuero	CARPI U.S.A.	Hydraulic and Civil Structure Construction and Repair
Gabriella L. Vaschetti	CARPI U.S.A.	Geosynthetics in Hydraulic Structure Rehabilitation
Andrew Weysham	Oceaneering	Commercial Diving/Underwater Construction

Membrane Repair System

The conceptual design included two membrane[1] repair systems; a drained system and a system without drainage. Both systems can be installed to prevent or reduce leakage into and through the structure. Generally speaking, the drained system should be used in cases where the repair area is wide, or where the repair area will not always remain totally submerged. The system without drainage may be suitable to prevent leakage at discrete locations under certain conditions.

[1] A glossary of terms is presented in Appendix A.

The drained system provides immediate and continuous discharge of water present between the concrete and the membrane whether the water is from the reservoir or within the structure. There are several benefits to this feature. The benefits are especially significant in cases where the temperature periodically drops below freezing. Discharging the water between the membrane and the structure reduces the probability of the water turning to ice or vapor which could exert stress on the liner and on the structure. By facilitating the removal of water which had previously infiltrated into the voids within the structure, the probability of further damage due to freezing and thawing is reduced.

The drained system also has special benefits in cases where the water level could fluctuate below the top of the repair area. By discharging water between the concrete and the liner, water will not become trapped behind the membrane and possibly cause sagging and damage to the membrane when the water level is drawn down.

The installation requirements are more stringent for the drained system than for the system without drainage. The high transmissivity of the drainage layer creates an air gap between the membrane and the concrete. The air in this gap is at atmospheric pressure, because the drainage layer is vented to the open air. Therefore, the seal must resist the full hydrostatic head of the water depths along the perimeter of the repair area.

The constructibility demonstration was focused on the drained system. Since installation of the drained system requires all of the steps of installation of the system without drainage, and the sealing performance requirements are more stringent, demonstration of the constructibility of the drained system would guarantee constructibility of the system without drainage.

The drained system consists of a flexible polyvinyl chloride (PVC) liner which is mechanically anchored to the structure with stainless steel profiles. Profiles are the batten strips which provide linear anchorage to the concrete structure. All submerged or potentially submerged anchorage must be watertight. The membrane is connected to the substrate with a watertight seal along the perimeter and at the intersection of adjoining sheets. Since all of the components at the interface of the seals are relatively noncompressible, a gasket is used to effect a seal.

Water between the liner and the concrete is conveyed through a highly transmissive layer installed behind the membrane to a collection point at the bottom of the installation where it can be discharged. Assembly details of the drainage layer, the membrane, and of the perimeter and splice joint profiles are shown in Figure 1.

Continuity of the seal along the perimeter and at seams between sheets is essential to prevent water intrusion behind the membrane. Continuity between two profile pieces is achieved by installing a splice plate which maintains compression on the membrane and gasket across the gap between the two adjacent

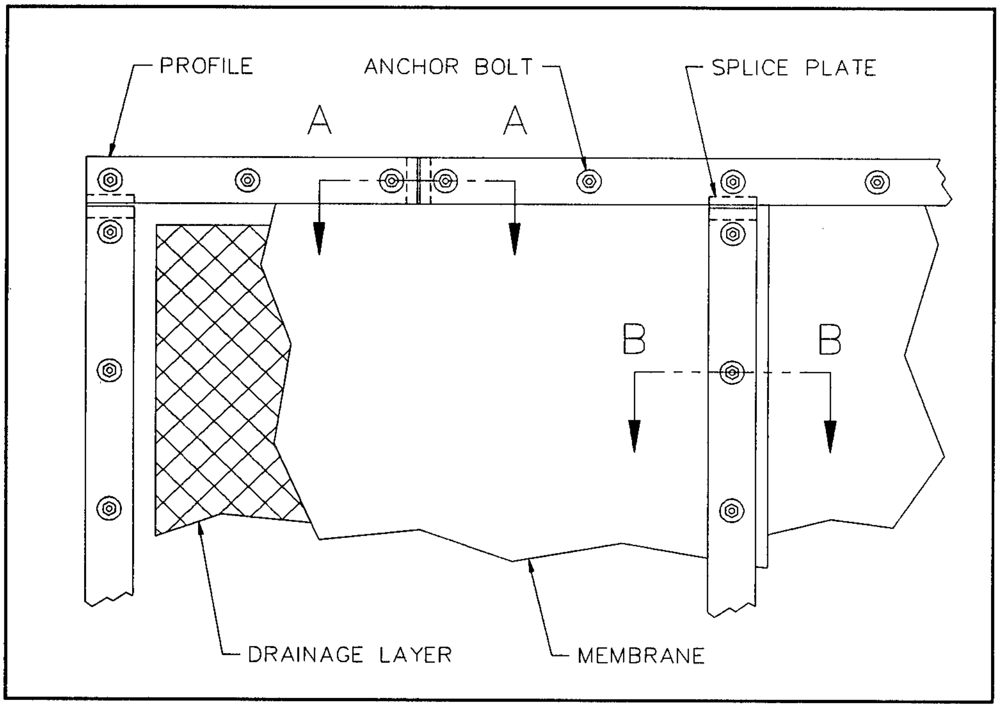


Figure 1. General assembly details of drained membrane repair system

profiles. Details of this are shown in the section from the assembly illustrations in Figure 2. Figure 3 contains details of how two adjoining sheets of membrane are sealed together forming a vertical splice.

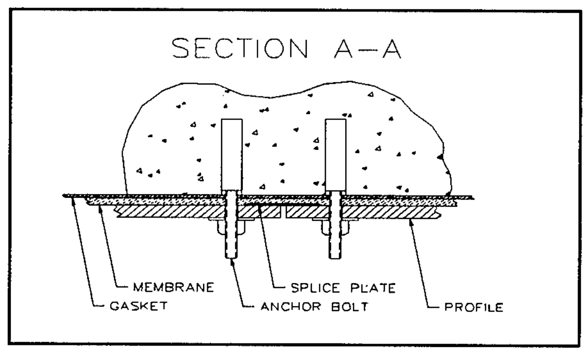


Figure 2. Section A-A of Figure 1

System Components

The following components were used in the feasibility demonstration. Selections were based on the results obtained in Phase I and on subsequent testing and experience. Catalog cuts for all materials are included in Appendix B.

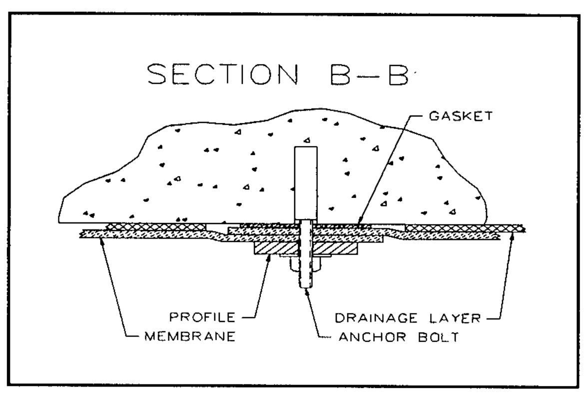


Figure 3. Section B-B of Figure 1

Membrane and drainage materials

The membrane material used is a very high-quality geocomposite, CARPI CNT, which is a PVC geomembrane coupled during extrusion to a pure polyester nonwoven, needle-punched geotextile backing. The basis for selection of a PVC

geomembrane is documented in the Phase I technical report. In selecting the membrane, special consideration was given to the fact that the membrane may be subject to direct sunlight throughout its service life. Therefore, the PVC must have excellent plasiticizers and be of a thickness sufficient to guarantee long life.

Drainage material requirements include sufficient transmissivity under potentially high hydrostatic heads. The drainage material is a tridimensional geonet with a preferential flow direction. A sample of the drainage material is shown in Figure 4. Note how the configuration of the drainage material is such that the water will tend to flow in one direction.

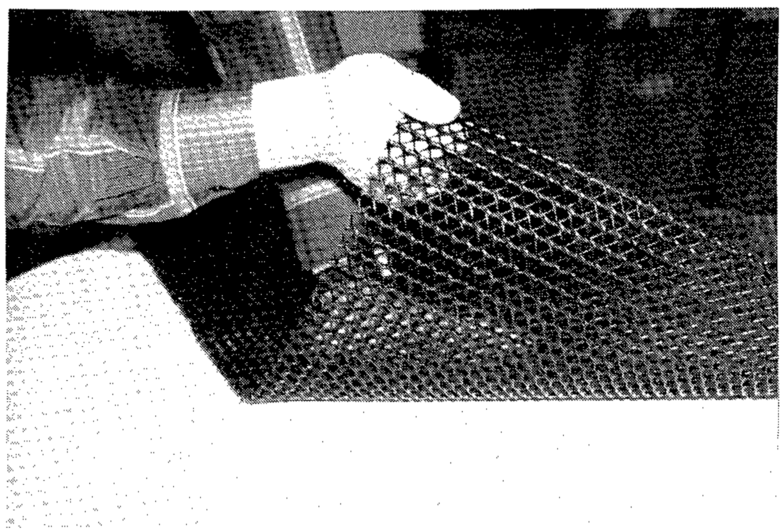


Figure 4. Sample of HDPE tridimensional geonet with a preferential flow direction

Mechanical fastenings

Stainless steel anchor bolts secure the profiles to the structure. Phase I results indicated that of several types of bolts commonly available, torque set bolts were best suited for the subject application. Chemical anchors which use a two-part epoxy and those which use a combination of a two-part epoxy and a glass encapsulated resin cartridge were also deemed suitable. For site-specific design, anchor bolt selection must take into consideration the bolt strength characteristics, the stress created in the concrete by the bolts, and the ability to install the bolts underwater.

Perimeter anchorage profiles and vertical splices were flat stainless steel bars. The bars are sized to provide sufficient stiffness to ensure continuous gasket compression without an excessive number of anchor bolts and with sufficient flexibility to conform to irregularities in the substrate.

Gasket material

Gasket material used for sealing along perimeter profiles and vertical splices is a high tack butyl rubber-based drawn sealant. This gasket material was substituted for the gasket originally recommend in Phase I as the material of choice due to the results of subsequent testing and experience. This material proved to be more adaptable to the substrate and was able to assure an efficient seal across a high-pressure differential.

Surface preparation material

Design for underwater installations should minimize required surface preparation of the structure to be repaired. To accommodate a rough surface, a surface preparation compound is applied to make the substrate smooth enough to obtain an effective seal. Two-part epoxy resin designed for underwater use was deemed suitable in Phase I.

Test Structure

A test structure was required to simulate a concrete hydraulic structure in need of repair. In an effort to make the constructibility demonstration comprehensive, the test structure was designed and built with features replicating possible situations which could complicate the underwater installation of the geomembrane system. These features included rough surfaces, complex corners, depressions and protrusions, a "V" shaped notch representing a construction joint, and various holes simulating discrete leakage points. The structure was designed in the shape of an "L" shaped wall as shown in Figure 5.

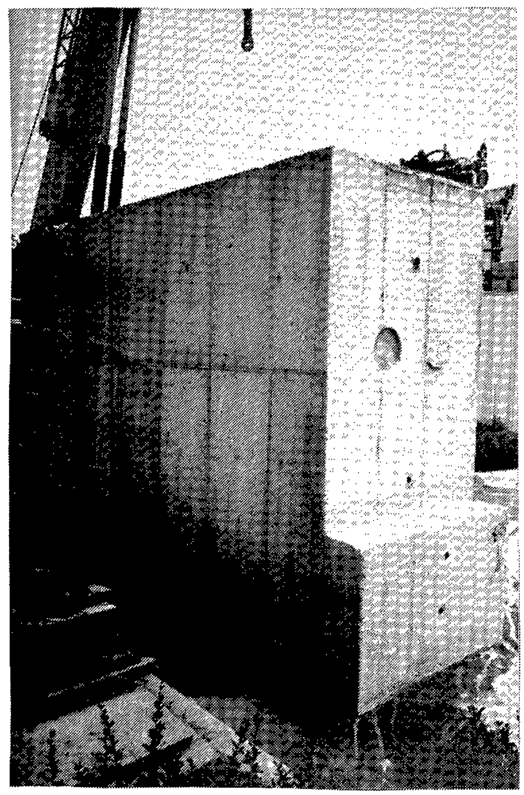


Figure 5. Concrete test structure built with features to complicate task of installing repair system underwater

A vacuum manifold was incorporated into the wall as shown in Figure 6. The manifold allows a suction to be drawn behind the membrane to simulate different hydrostatic heads and to test the efficiency of the system. The manifold is connected to 1-1/2-holes in the concrete which simulate points of discrete leakage through the structure.

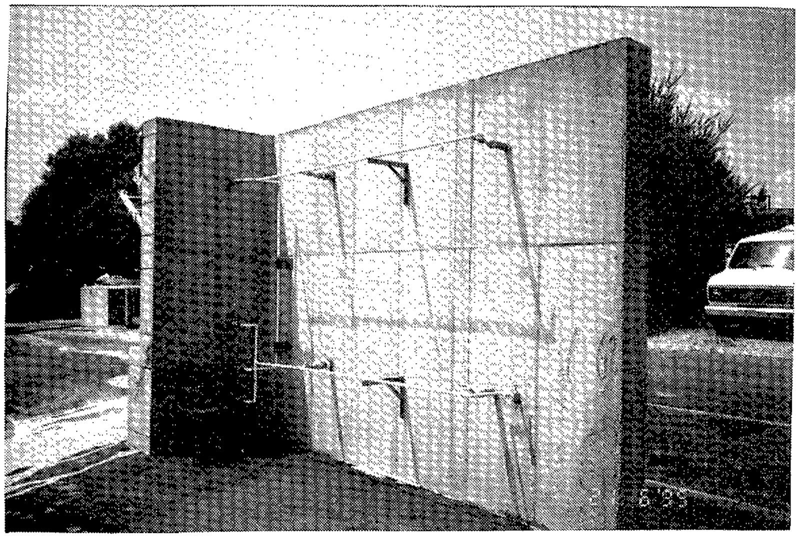


Figure 6. Vacuum manifold installed on wall to simulate leakage through structure and to evaluate performance of repair system

System Design

The repair system was divided into three separate compartments. This is in accordance with what is practiced during actual installations. Compartmentalization allows installation of membrane panels of suitable dimensions and allows independent evaluation of the behavior of the system in different sections. Also, the structure was designed so that each compartment would represent a different situation which could be separately evaluated as related to the ease of system installation and the efficiency of the watertight seal.

Compartment 1 includes the area with the roughest substrate and with the simulated construction joint. Compartment 2 includes the area with a smoother substrate and no particular irregularities. Compartment 3 includes concave and convex irregularities and corners. Vertical seals were used to separate the compartments and to ensure water tightness. Vertical seals were also used at splices between adjacent sheets of membrane. A prefabricated membrane sheet was designed for Compartment 3. The general arrangement of the various compartments on the test structure is shown in Figure 7.

Surface conditions will dictate design of the gasket system on smooth surfaces, the gasket can be installed directly on the structure, while rough surfaces may require some preparation prior to gasket installation.

Construction joints intercepting the anchorage profiles are zones of high potential for water infiltration. One solution to this problem is to use a

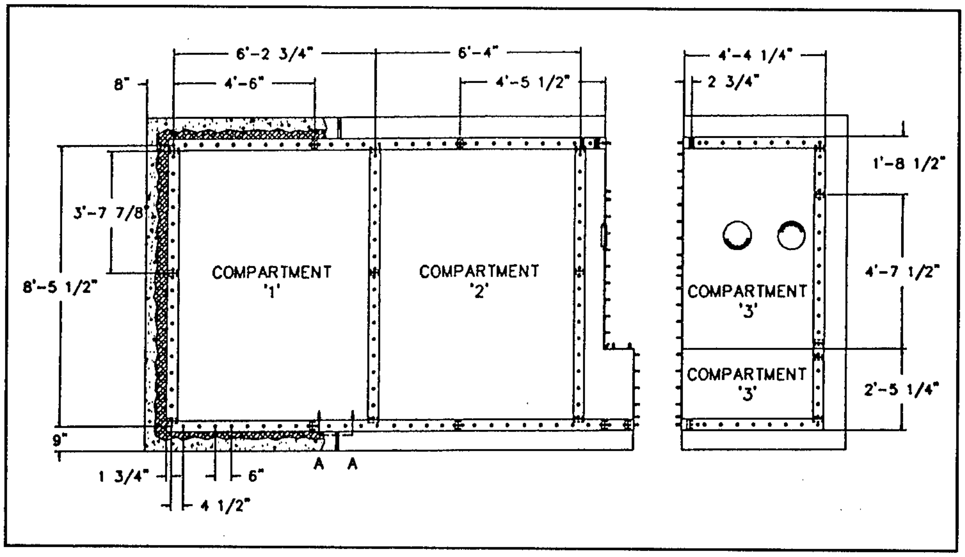


Figure 7. General design of repair system for test structure

compressible and adjustable material capable of following the movements of the joints. A soft neoprene seal cut to fit the joint while compressed was used (Figure 8).

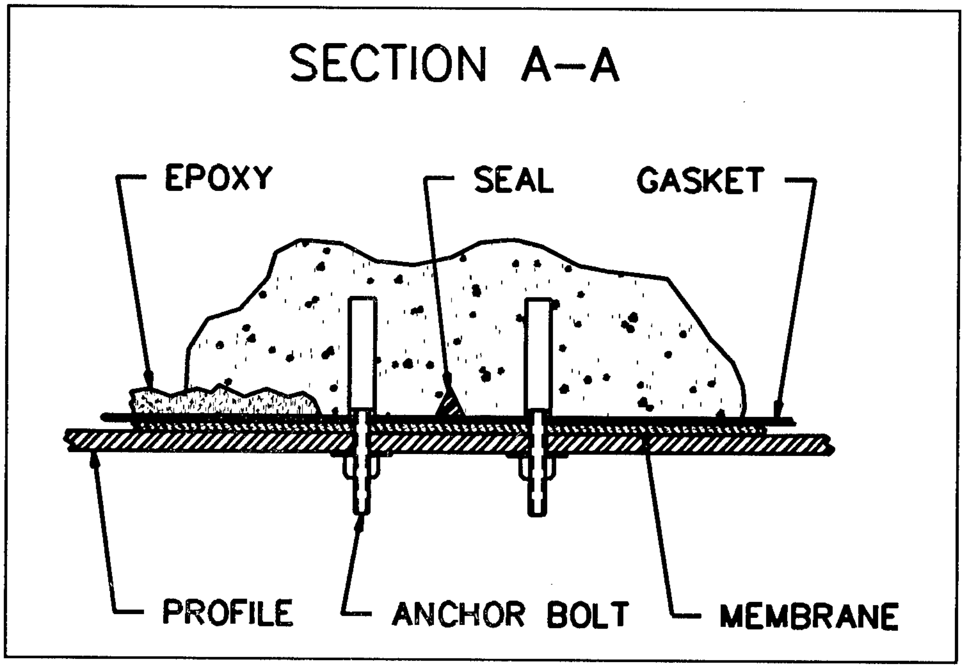


Figure 8. Section A-A of Figure 7

Specifications for materials used in the constructibility demonstration are summarized in the following table. Additional information is given in Appendix B.

Table 2
Component Specifications for Demonstration

ITEM	DESCRIPTION	SPECIFICATION
1	Membrane	2.5-mm-thick PVC stabilized for ultraviolet exposure backed with 500 g/m^2 nonwoven geotextile.
2	Drainage Layer	250-mm-thick HDPE tri-planar geonet with 50% compression at 15,000 psf (force).
3a	Anchor Bolts	1/2- x 7-in. SST wedge type expansion anchors.
3b	Anchor Bolts	1/2- x 6-in. SST threaded rod; parallel tube cartridge of resin and hardener with ultimate bond strength ≥ 5,000 lb with 4-in. embedment in f'c ≥ 2,300 psi concrete.
3c	Anchor Bolts	1/2- x 6-in. SST threaded rod; parrallel tube cartridge of resin and hardener with ultimate bond strength ≥ 5,000 lb with 4-in. embedment in f'c ≥ 2,300 psi concrete and glass encapsulated vinylester resin and hardening agent.
4	Profile	5/16- x 4-in. SST flatbar with 9/16-in. holes spaced on 6-in. centers.
5	Gasket	High tack butyl rubber based drawn sealant with S.G. of 1.1; 40 mm x 2 mm.
6	Surface Preparation Compound	Two-part epoxy resin designed for underwater use.

Test Facility and Special Tools

In addition to commonly used items, special facilities and equipment were required.

Test tank

The water tank at the Oceaneering Maryland facility designed for testing and evaluating submersible systems and equipment (Figure 9) was used for the constructibility demonstration. This tank is 30 ft in diameter and 20 ft deep, with filtered water, multiple viewing ports, crane access, and electrical power.

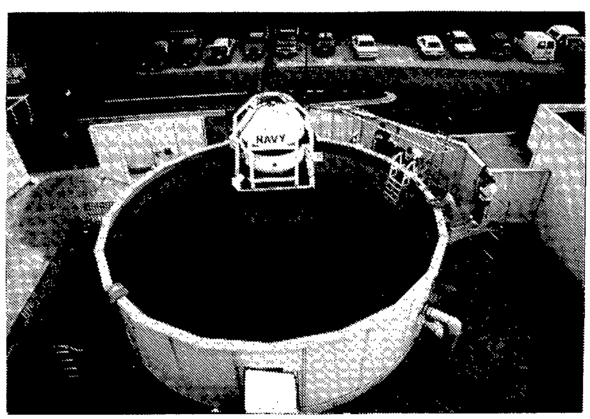


Figure 9. Tank for testing underwater equipment

PVC welding equipment

An electric hot-air welding tool and hand roller (Figure 10) were used to fabricate the piece of membrane which covered the complex corner. These items are standard tools used in the geosynthetics industry.

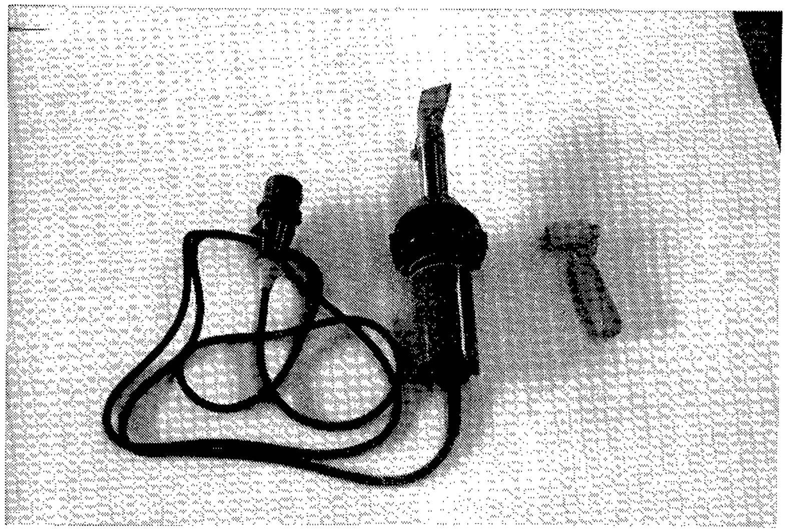


Figure 10. Welding equipment for joining PVC membranes

Hydraulic hammer drill

A hydraulic hammer drill (Figure 11) sealed for underwater use and powered by a topside 10-hp unit was used by the divers to drill holes for the anchor bolts. The tool was made neutrally buoyant underwater by attaching a plastic container partially filled with air.

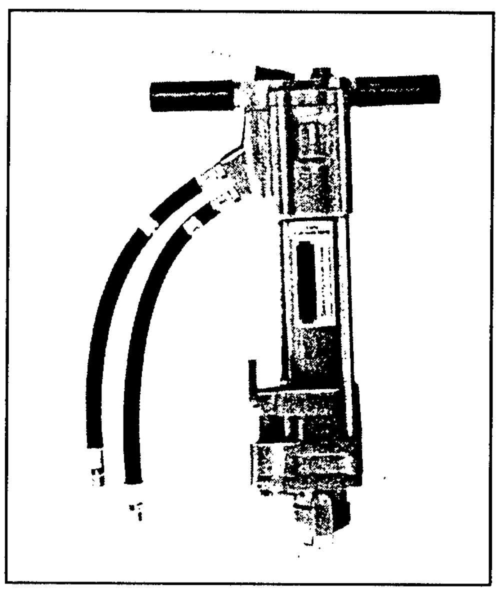


Figure 11. Hydraulic hammer drill

Diving equipment

Standard commercial diving equipment was used for the demonstration. A 25-cfm air compressor served as the primary air source, and a high-pressure bottle fitted with a high-flow regulator was used as standby. Additionally, emergency "bailout" bottles were

worn by the divers. Two-way radios were used to maintain constant communication between the divers and the topside diving supervisor. An underwater video camera with a topside monitor and a video recorder was used to document the operation.

3 Constructibility Demonstration

The constructibility demonstration was planned to be conducted in three progressive steps:

a. Dry installation

b. Limited underwater installation

c. Full underwater installation

Dry Installation

The first installation was accomplished in the dry to familiarize the diving crew with the materials and the installation techniques. During the dry run, the entire system was installed on the test structure by the diving crew, under the instructions and supervision of an expert technician from CARPI experienced in conventional membrane installations.

The stainless steel flat bar was punched with 9/16-in.-diam holes spaced on 6-in. centers, which was considered close enough spacing to allow optimum efficiency for the compression of the chosen gasket material without overstressing the concrete. The pieces were cut to provide the profile sections detailed in the design and numbered to ensure correct positioning during the installation. The profiles then served as templates to allow accurate drilling of the holes for the anchor bolts (Figure 12).

Two types of anchor bolts were installed along the perimeter. The research team decided to test the expansion anchors, as well as the chemical anchors, to directly compare installation efficiency and rates in the dry and underwater. Prior to anchor installation, debris was cleaned out of the holes with a pressure hose. The injection equipment for the two-part epoxy resin used for the chemical anchors is shown in Figure 13. Subsequent to anchor setting, all profiles were placed on the structure to verify proper alignment. Profiles were then removed.

Figure 12. Profile pieces are used as a template to ensure correct positioning as anchor bolt holes are drilled in concrete

Figure 13. Injection of two-part epoxy resin for chemical anchor bolts

The simulated construction joint was treated to avoid water intrusion behind the membrane. The joint was filled with an 8-in. soft neoprene seal cut to fit the joint under the perimeter profile, as shown in Figure 14. The seal was bonded to the substrate with epoxy resin.

HDPE geonet sheets were cut to fit the areas within the profiles which formed the boundaries of each compartment. The geonet sheets were secured to the structure surface with small expansion anchors, as shown in Figure 15.

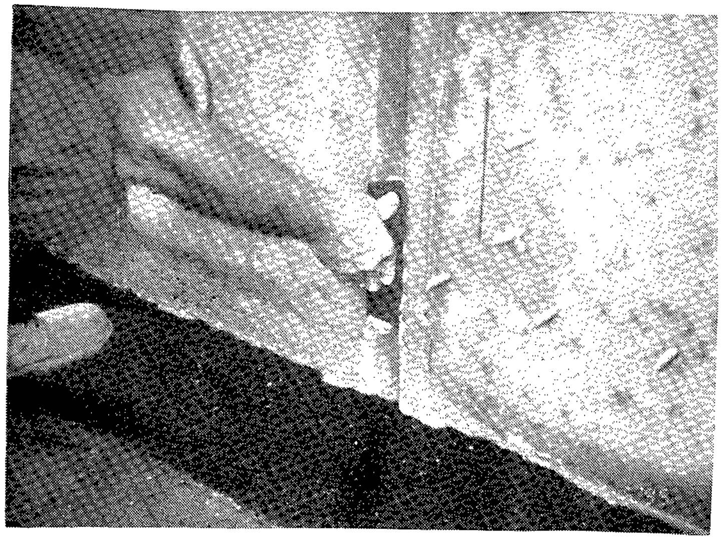


Figure 14. Installation of neoprene rubber cut to fit construction joint to allow continuous seal of repair system to concrete

Installation proceeded with preparation for the perimeter seal. Since thicker sections of the gasket material was unavailable, two layers were assembled to obtain the desired thickness. In compartments 2 and 3, the gasket material was installed directly on the smooth concrete surface (Figure 16). At compartment 1, the surface preparation compound was used to smooth the rough substrate prior to gasket installation (Figure 17).

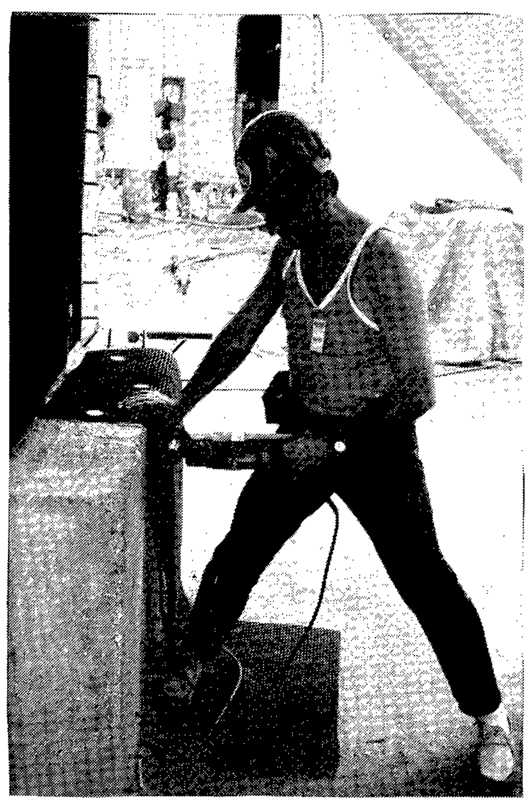


Figure 15. HDPE geonet drainage layer being secured to concrete with small expansion anchors

PVC geocomposite sheets cut to fit compartments 1 and 2 and the prefabricated PVC sheet for compartment 3 were then positioned on the structure. The sheets where punctured to allow insertion over the anchor bolts and overlapped 8 in. at junctions between compartments. Care was taken in placing the sheets to avoid wrinkles and slack areas which could potentially cause stress concentrations.

The perimeter and splice profiles were positioned and fastened to the structure. Splice plates were installed, as shown in Figure 18. After all profiles had been installed, further tightening was accomplished to better secure the membrane to the structure. The completed installation in the dry is shown in Figure 19.

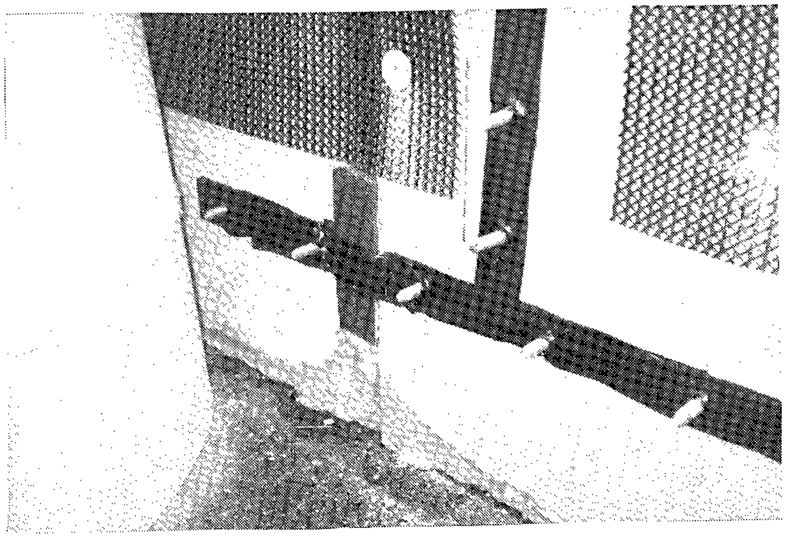


Figure 16. Gasket is placed directly on concrete when concrete is in good condition

Figure 17. Surface preparation compound being applied to rough concrete at perimeter of compartment 1

To test efficiency of the dry installation, a pneumatic eductor was connected to the manifold and a suction equivalent to a hydrostatic head of approximately 28 ft of water was applied. The suction action made the liner conform to the structure. The vacuum valves were closed and the eductor was disconnected from the structure leaving the membrane conformed to the substrate. After 24 hours, the membrane was still tightly conformed to the structure (Figure 20) indicating an excellent seal.

Considerations for Underwater Test

With respect to the components, it was concluded that the materials selected for the dry installation were suitable for the underwater installation. As for procedures, it was discussed whether the epoxy resin surface preparation should be placed prior to anchor bolt installation, which is, from an operational standpoint, easier. Since the epoxy resin stiffens as it hardens, it is possible that vibrations caused by drilling of anchor bolt holes could cause small cracks in the surface preparation compound, or separation at the epoxy resin-concrete interface which would jeopardize the seal. Experimentation was inconclusive, so it was decided to install anchor bolts before applying the surface preparation compound to be conservative.

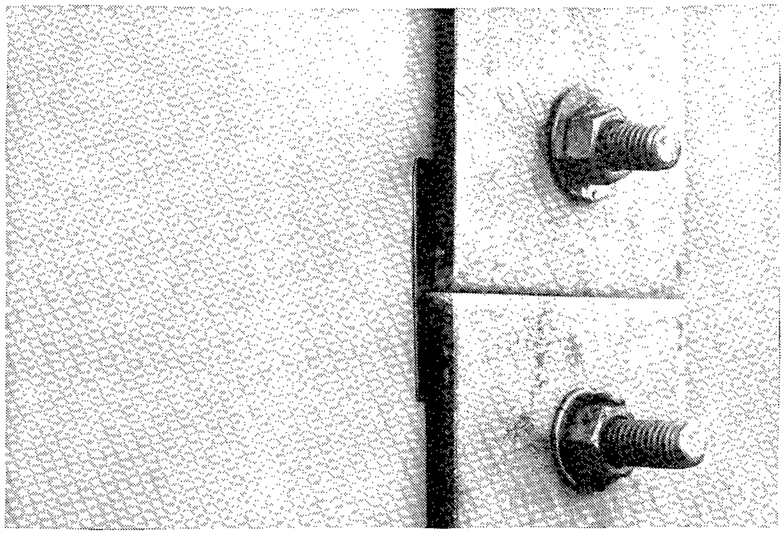


Figure 18. Splice plate provides continuous compression of membrane and gasket across span where profile pieces meet

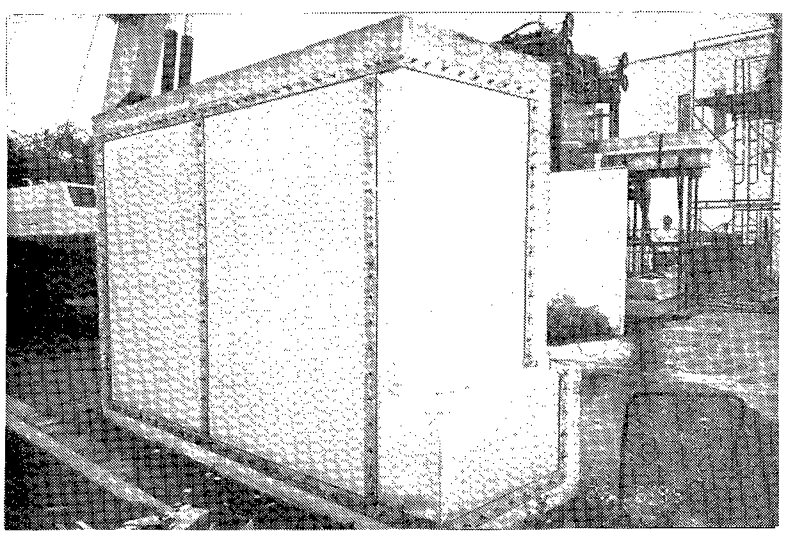


Figure 19. Completed dry installation

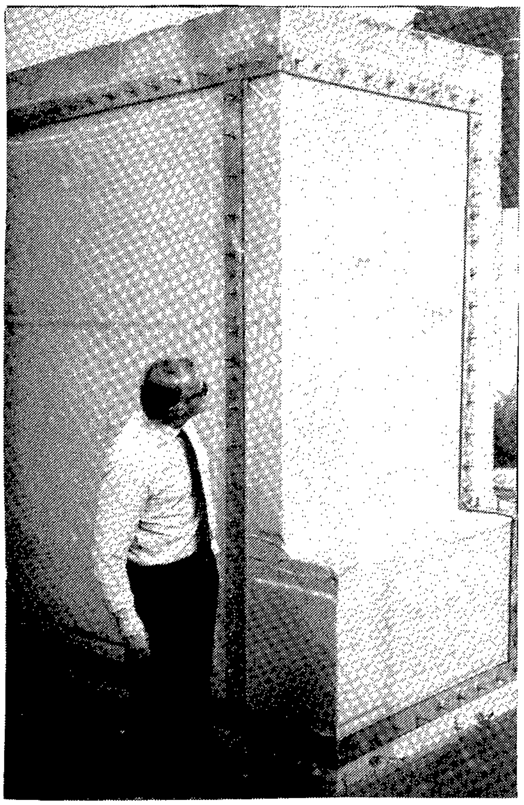


Figure 20. Twenty-four hours after shutting off vacuum pump the membrane was still tightly conformed, indicating excellent impermeability of the system

Limited Underwater Installation

After successfully installing the repair system in a dry environment, the next step was to test what was believed to be the most difficult part of the underwater installation: sealing the membrane to a rough concrete substrate.

The repair system, minus the anchor bolts and the geonet on compartment 1, was removed from the wall. A 4-ft-long section of the epoxy resin which was used to smooth the rough concrete was removed from the wall with a hammer and chisel (Figure 21).

The wall was then lifted with a 60-ton crane as shown in Figure 22 and lowered in the test tank to a depth of 20 ft. Divers applied underwater epoxy to the rough surface replacing the 4-ft section which was removed. The gasket was placed around the perimeter of compartment 1, and a new sheet of PVC geocomposite was cut and placed on the wall. The stainless steel profiles and splice plates were installed and the nuts were tightened with a pneumatic wrench. Water was evacuated from between the geomembrane and the concrete with a hydraulic ejector. As the suction was applied, the geomembrane conformed to the substrate. The

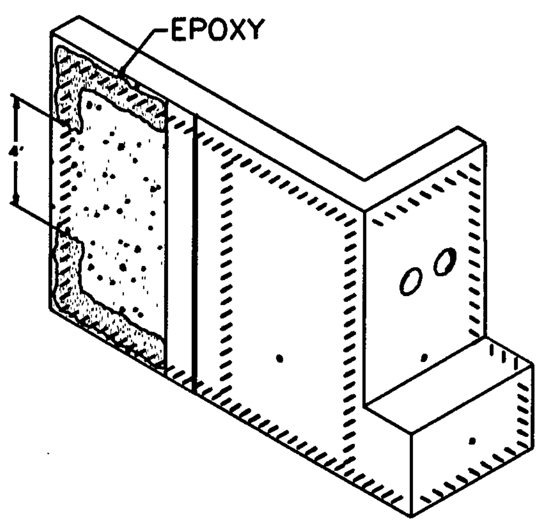


Figure 21. Four feet of surface preparation compound was removed from rough concrete prior to lowering the wall underwater

valves on the vacuum manifold were closed, isolating the ejector from the repair system. Two weeks later the geomembrane remained sucked up against the substrate, indicating that any water seepage through the repair system was negligible.

Full Underwater Installation

A second test of the system was performed to demonstrate that all components of the system could be effectively installed underwater. With the exception of the anchor bolts, all repair system components were removed from the wall. A new set of bolts was installed underwater along the left side of compartment 1 as shown in Figure 23.

Holes for the anchor bolts were drilled with a hydraulic hammer drill powered by a 10-hp hydraulic power unit on the surface. Appropriate profile sections were again used as a template for divers to drill the bolt holes (Figure 24). Water was injected into the bolt hole to clear debris, and the epoxy resin was injected as shown in Figures 25 and 26, respectively.

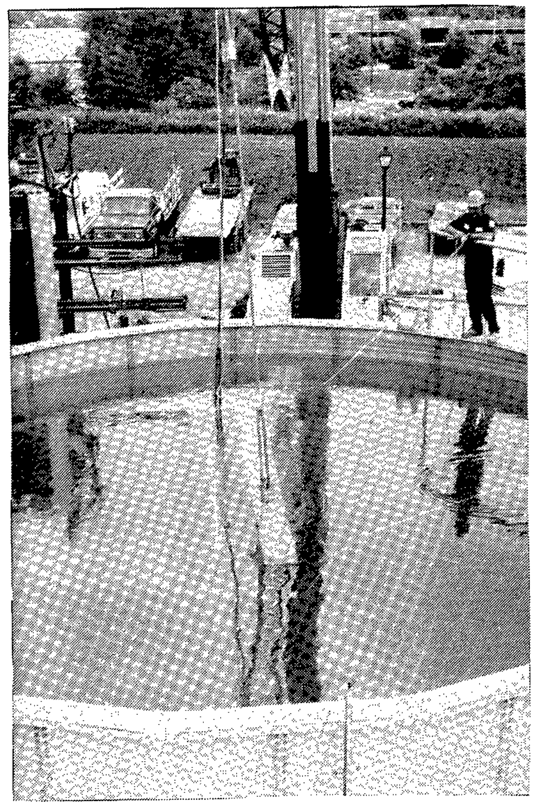


Figure 22. Test structure was lowered into test tank to a depth of 20 ft

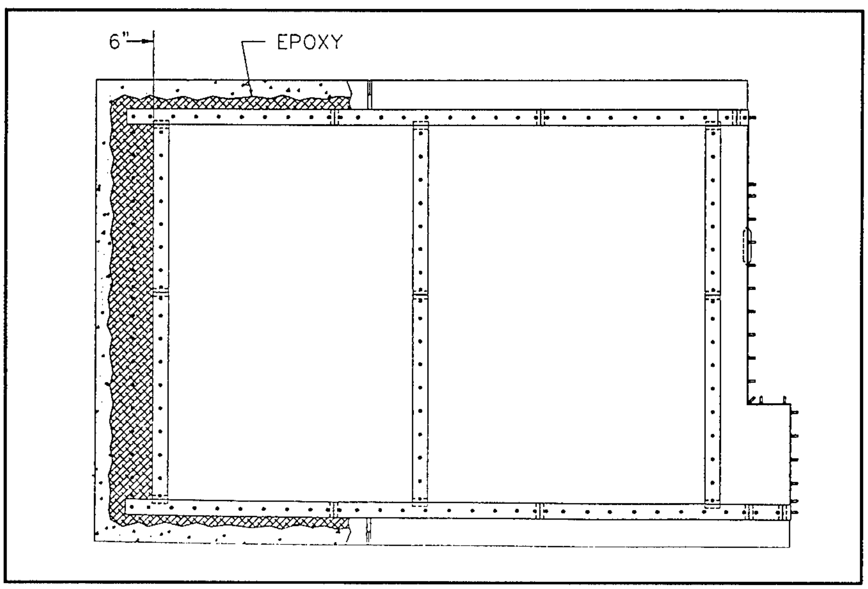


Figure 23. Layout for full underwater installation

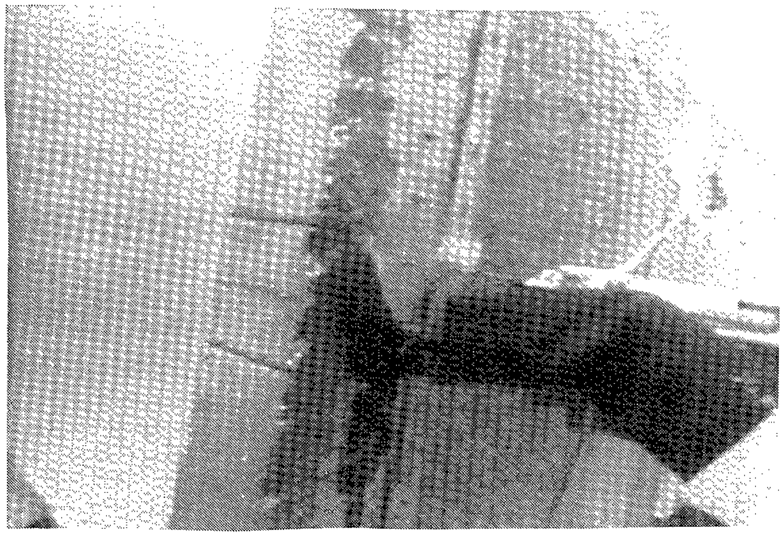


Figure 24. Diver drilling anchor bolt hole with hydraulic hammer drill

Figure 25. Water is injected to clean bolt holes

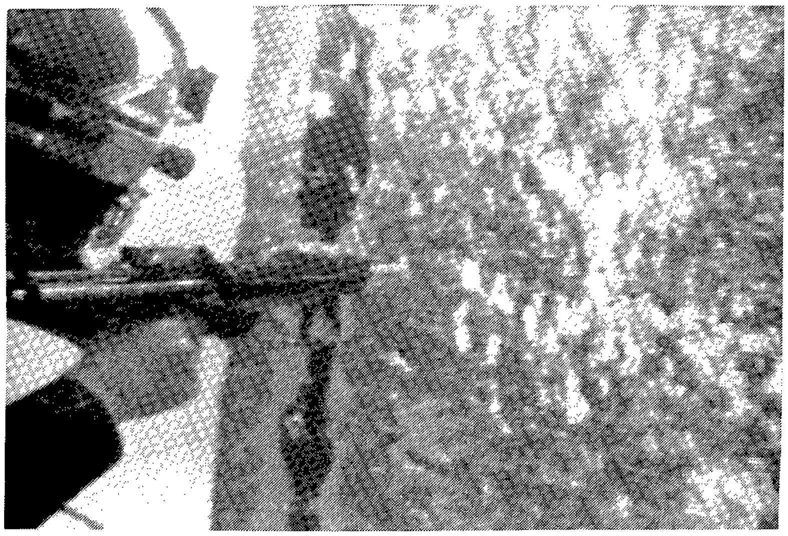


Figure 26. Diver injecting epoxy resin into bolt hole

Three types of anchor bolts were installed: mechanical torque set or wedge anchors, chemical set anchors using a two-part epoxy resin, and chemical set anchors using a combination of two-part epoxy resin and glass encapsulated resin cartridge.

The rough concrete substrate along the new bolt pattern was smoothed with the underwater epoxy as shown in Figure 27. A wedge of neoprene rubber cut to fit the construction joint was secured to the wall at each of the two locations where the profile would cross the joint. The same underwater epoxy resin used to smooth rough surfaces was used to bond the rubber wedges.

Figure 27. Surface preparation compound being applied to rough concrete at perimeter of repair area

Sheets of geonet were cut such that when installed on the wall, the edges of the geonet pieces would be inset approximately 2 in. from the edge of the profile. The geonet drainage layer was secured to the wall with small expansion anchors. Positioning of the drainage layer is shown in Figure 28. The gasket was installed along the bolt pattern, as shown in Figure 29. Three sheets of PVC geomembrane were installed on the wall; two new pieces were

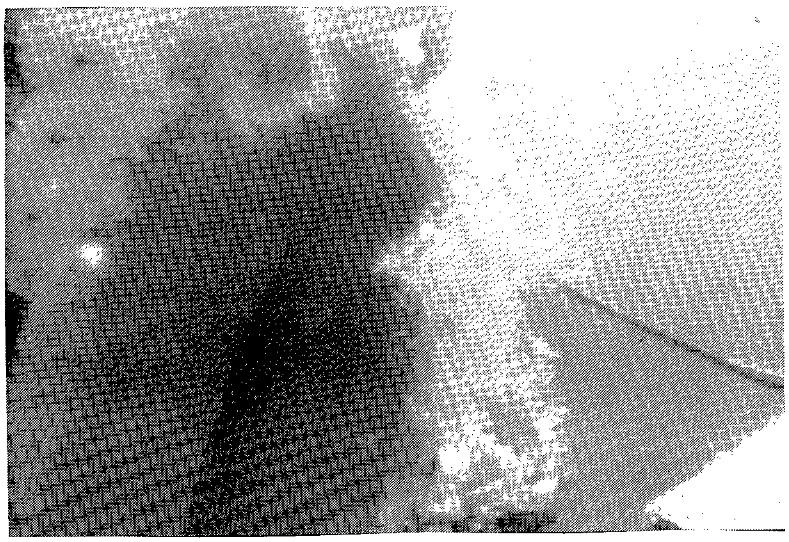


Figure 28. Divers positioning drainage layer

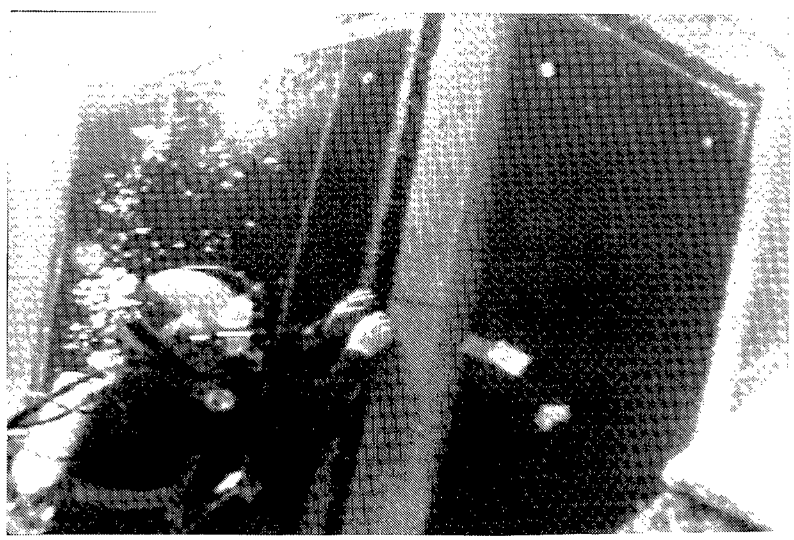


Figure 29. Underwater placement of gasket

pieces were used for the flat portions of the wall, and the prefabricated piece was used for compartment 3. The membrane sections were deployed into the water and rolled down the face of the wall as shown in Figure 30. To avoid misalignment problems, bolt holes were not precut in the membrane. Holes were punched by tapping the membrane with a hammer directly over the bolts as shown in Figure 31. The stainless steel profiles and splice plates were

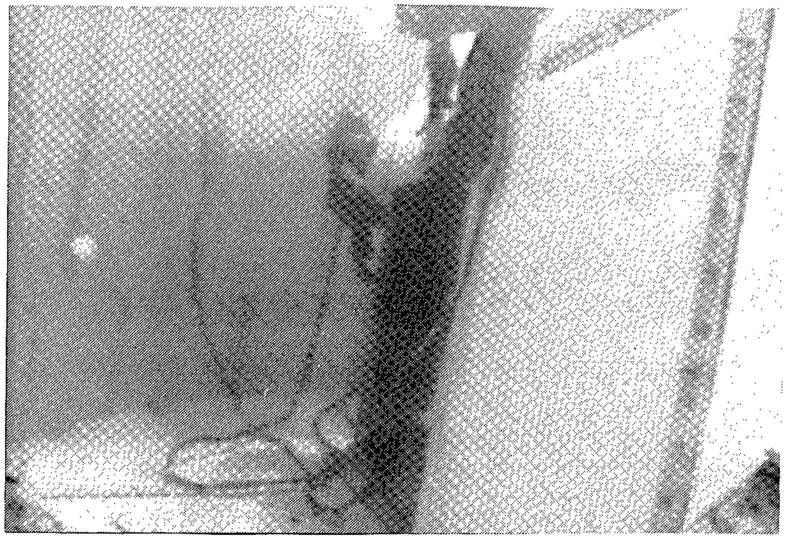


Figure 30. Impermeable membrane being rolled down face of wall

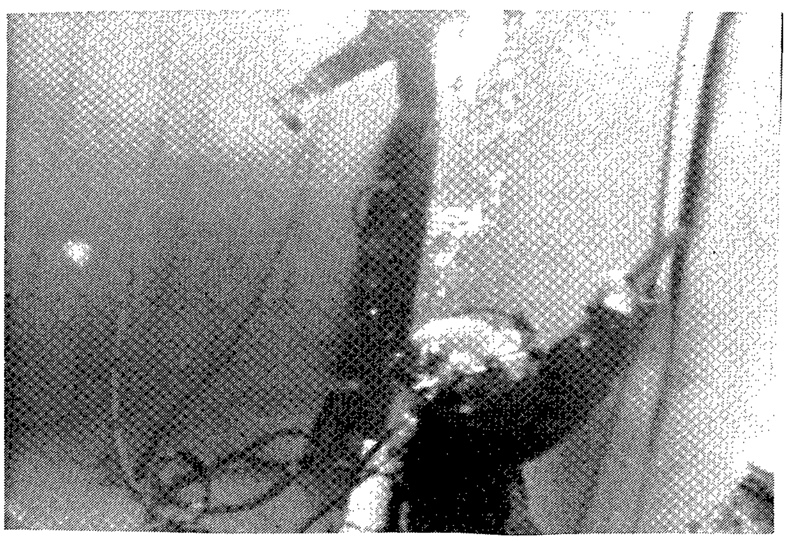


Figure 31. Diver tapping holes in the membrane over anchor bolts

installed and the nuts were tightened. Five of the six anchor bolts which were installed underwater using a combination of two-part epoxy resin and glass encapsulated resin cartridges became loose as torque was applied. The evaluation continued to determine the effect of the failed anchor bolts. Water was evacuated from between the geomembrane and the concrete with the hydraulic ejector. As the suction was applied, the geomembrane conformed to the substrate. The valves on the vacuum manifold were closed, isolating the ejector from the repair system.

The membrane on compartments 2 and 3 of the wall remained sucked tight against the wall, but compartment 1 slowly loosened over a period of

approximately 2 hr. The vacuum was reapplied, and a diver entered the water to investigate. By injecting liquid dye as shown in Figure 32, a diver found a slow leak in the vicinity of the defective bolts. The defective bolts were removed, and replacement bolts were installed underwater. The suction was reapplied, and no leakage was detected. The membrane remained tightly adhered to the substrate as shown in Figure 33.

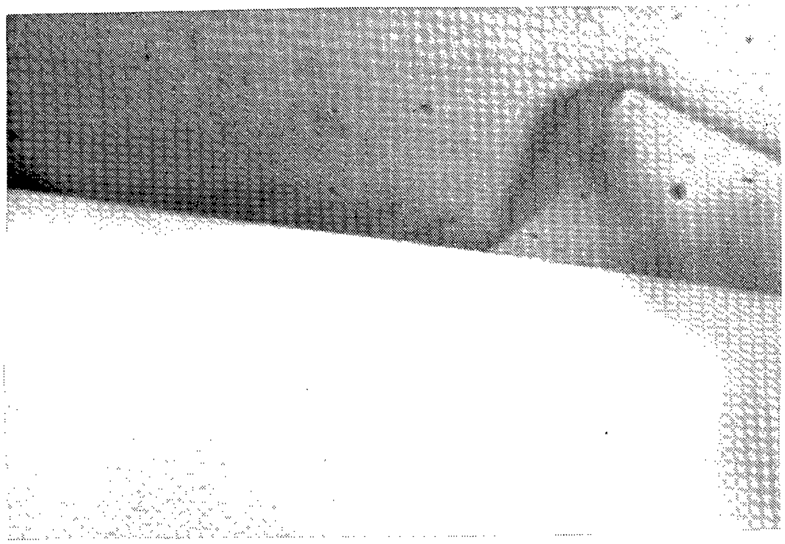


Figure 32. Dye injected into water to detect seepage

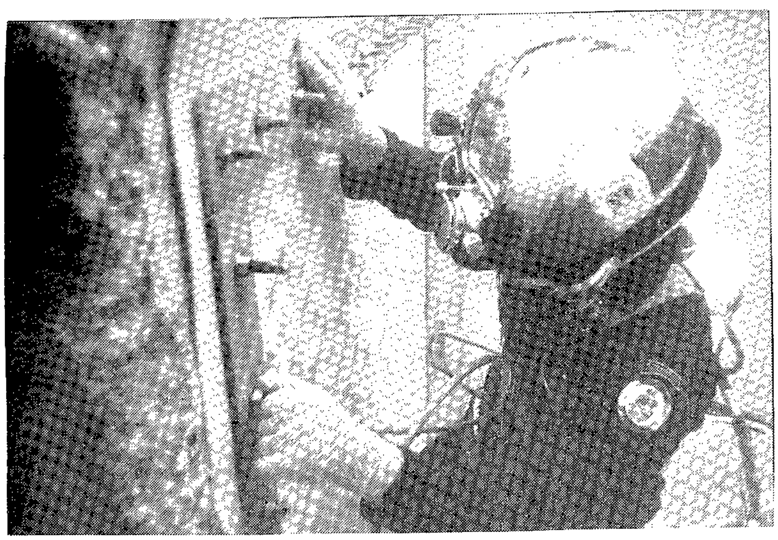


Figure 33. Membrane tightly conformed against substrate

The leakage attributed to the defective bolts is a common concern for bolts installed underwater. Besides being mixed in a water environment, the lack of control when drilling the holes could cause oversized holes that in turn can cause the mixing of the epoxy to be incomplete. The exercise suggests that for underwater installations, mechanical-set anchor bolts are more reliable than epoxy-set anchor bolts.

4 Discussion

Interpretation of Results

Two basic issues were addressed in evaluating results of the underwater installation:

a. Installation constructibility

b. Sealing efficiency of the system

From the standpoint of installation feasibility, the underwater test demonstrated that ease of installation depended on the roughness of the substrate and the geometry of the structure. In rough areas, detailed procedures were required to ensure good perimeter sealing, while on fairly smooth surfaces, installation of all components was easily accomplished. Experience in the dry had already shown this, but environmental conditions underwater amplified the problems associated with difficult features. This mirrored experience in dry installations and showed that additional care was required to ensure good perimeter sealing when performing installations in the more challenging underwater environment.

The research team believed that particular geometries of the structure, specifically the complex corners in compartment 3, should be treated with a prefabricated sheet. Such scenarios must be addressed individually for each installation. Structures with complex shapes such as intake towers may require prefabricated membrane sections to reduce installation time. Protrusions and depressions may constitute a design issue if they are very sharp. Experience in the dry, however, has proven that such irregularities can be adequately addressed with additional transition layers of nonwoven, needle-punched geotextiles.

Testing the system revealed that seepage through the repaired area was very slow. Even where five adjacent anchor bolts failed, leakage was slow enough to make detection of the leak difficult to notice even when dye was injected at the point of leakage. Although the leakage rate was not measured, the research team believes that it was slow enough to be negligible with respect to the requirements of the most concrete hydraulic structures. The use of a drained system helped to locate and rectify the leak.

Guidelines for Design and Procedures

Since surface conditions and geometry of the structure to be repaired are very important, design of the repair system will have to be based on a detailed survey of existing conditions. In the case of smooth surfaces, with no particularly complex shapes, a basic design including material specifications, perimeter sealing features and procedures, and general installation procedures may be adequate. In the case of rough surfaces, the design must take into account perimeter sealing with particular care. This could justify further investigations on new gasket materials available on the market, which must be carefully tested to verify suitability and cost effectiveness as compared to a traditional surface preparation.

If the structure to be repaired has difficult shapes, an evaluation has to be made of the perimeter seal required to accommodate these features. The evaluation must consider the operational aspects of installation, the potential problems of overstressing the substrate in case the anchorage points are too close, and the time and costs involved with such a choice. In these cases, prefabricating the membrane sections should be considered to minimize the above effects.

With respect to material selection, the research team aimed to demonstrate a system using the materials which had been determined most suitable in Phase I. Other materials have been discarded because they were deemed unsuitable for the project. The following materials and related properties offer general design guidelines.

Table 3
Design Guidelines for Component Selection

Component	Design Guidelines
Membrane	PVC with geotextile backing; Loading of membrane and exposure to sunlight must be taken into consideration while specifying minimum performance characteristics.
Drainage Layer	Geonet; Adequate transmissivity at the highest possible hydrostatic head while compressed between chosen membrane and substrate must be assured.
Anchor Bolts	Stainless Steel Wedge Anchor Bolts; Chemical Anchor Bolts may be used in cases where bolt spacing must be too close to allow the use of wedge anchors, but special attention must be paid to installation techniques.
Profiles	Stainless Steel Flat Bars are usually adequate, but if the concrete surface is plain, a profile with a greater section modulus may be desirable (e.g., a channel shape); Stiffness of the profile should take into account the severity of undulations on the substrate, and bolt spacing should be specified accordingly (A stiffer profile allows greater bolt spacing).
Gasket	High Tack Butyl Based-Sealant drawn as thin as possible, but thick enough to accommodate roughness of the substrate.
Surface Preparation Compound	If needed, a two-part epoxy resin such as Schull Underwater Gel which will adhere to concrete underwater and maintain its integrity can be used.

The cost to perform underwater installations of geomembrane repair systems will vary significantly from project to project. The cost during the underwater constructibility demonstration was approximately $93 per square foot. The small scale of the demonstration resulted in higher unit costs due to poor economy of scale. Factors which influence the unit cost include the size of the repair area, geometric complexity of the structure, roughness of the substrate, accessibility to the work site, water depth, water visibility, and altitude of the project site. Generally speaking, material costs for a project will be roughly 5 to 10 percent of the total project cost.

5 Conclusions and Recommendations

The successful underwater installation of the membrane repair system developed in Phase I demonstrated the feasibility of the system. Although results of the demonstration are more qualitative than quantitative, it is evident that the system is constructable and will perform acceptably if designed and installed correctly.

The research team recommends confirming the applicability of the membrane repair system in the field through a full-scale prototype underwater installation on an existing concrete hydraulic structure. If possible, the prototype repair should be installed on a structure where leakage can be measured. This will allow quantitative evaluation of how well the membrane system prevents leakage over time.

Appendix A
Glossary of Terms

geocomposite---a manufactured material using geotextiles, geogrids, geonets, and/or geomembranes in laminated or composite form; in this text, geocomposites referred to are geomembranes coupled with geotextiles.

geomembrane---a membrane with very low permeability used as a liquid or vapor barrier with foundation, soil, rock, earth, or any other geotechnical engineering related material as an integral part of a human-made project, structure, or system.

geonet---a netlike polymeric material formed from intersecting ribs integrally joined at the junctions used for drainage with foundation, soil, rock, earth, or any other geotechnical-related material as an integral part of a human-made project, structure, or system.

geosynthetics---the generic term for materials used in geotechnical engineering applications; it includes geotextiles, geogrids, geonets, geomembranes, and geocomposites.

geotextile---any permeable textile used with foundation, soil, rock, earth, or any other geotechnical engineering-related material as an integral part of a human-made project, structure, or system.

membrane---general term to indicate a geomembrane or a geocomposite.

nonwoven---for geotextiles, a planar and essentially random textile structure produced by bonding, interlocking of fibers, or both, accomplished by mechanical, chemical, thermal, or solvent means and combinations thereof.

neoprene---an elastomer, polychloroprene, formed by adding hydrogen chloride to monovinylacetylene.

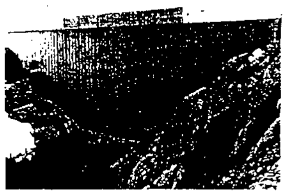
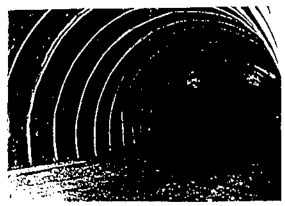
profile---the batten strip used to provide linear anchorage of the membrane to the upstream face of the dam; profiles are often designed, based on site-specific conditions, to provide pretensioning during installation to remove wrinkles from the membrane and to provide a conduit to the water collection and drainage system.

transmissivity---for a geonet, the volumetric flow rate per unit thickness under laminar flow conditions within the plane direction of the geonet.

Appendix B
Catalog Excerpts

SIBELON CNT

SIBELON


CHARACTERISTICS	TEST METHOD	UNIT	VALUES			
			CNT 1500	CNT 2200	CNT 2800	CNT 3750
Composition	-					
PVC Geomembrane - Thickness		mm ± 10%	1.0	1.5	2.0	2.5
PET Geotextile - Weight		g/m²	200	200	200	500
Cold bending	UNI 8202/15					
MD		°C	< - 35	< - 35	< - 35	< - 35
CMD		°C	< - 35	< - 35	< - 35	< - 35
Tensile Resistance	UNI 8202/8					
GEOTEXTILE						
Tensile strength at break - MD		kN/m	≥ 8	≥ 8.5	≥ 10	≥ 20
Tensile strength at break - CMD		kN/m	≥ 8	≥ 8.5	≥ 10	≥ 20
Elongation at break - MD		%	≥ 35	≥ 40	≥ 40	≥ 40
Elongation at break - CMD		%	≥ 35	≥ 40	≥ 40	≥ 40
GEOCOMPOSITE						
Tensile strength at break - MD		kN/m	≥ 9	≥ 13	≥ 18	≥ 23
Tensile strength at break - CMD		kN/m	≥ 8.5	≥ 12	≥ 18	≥ 23
Elongation at break - MD		%	≥ 100	≥ 180	≥ 200	≥ 230
Elongation at break - CMD		%	≥ 100	≥ 180	≥ 200	≥ 230
Tear Resistance	ISO 4674-A2					
MD		N	≥ 85	≥ 100	≥ 120	≥ 200
CMD		N	≥ 80	≥ 100	≥ 120	≥ 200
Puncture Resistance	UNI 8202					
Dinamic	/12	-	PD3	PD3	PD4	PD4
Static	/11	-	PS5	PS5	PS5	PS5
Impermeability	UNI 8202/21 500 kPa	-	Imp.	Imp.	Imp.	Imp.

SIBELON S.r.l.
Via S.Eusebio, 4 - 28047 OLEGGIO (No) - ITALY
ph. ++39/321/94855 - fax. -+39/321/91193

TENAX GNT™ 100

HIGH PERFORMANCE TRI-PLANAR GEONET

TENAX GNT™ 100 is an innovative high performance tri-planar geonet. The three sets of intersecting strands form unique flow conduits that provide extremely high flow capacity, high compressive resistance and enhanced tensile properties. TENAX GNT™ 100 is manufactured from the extrusion of high density polyethylene resin and carbon black. TENAX GNT™ 100 is inert to chemical and biological attack and is stabilized against UV degradation.

PROPERTIES	TEST METHOD	QUALIFIER	UNIT	VALUE	Note
GEONET CORE					
TENSILE STRENGTH	ASTM D4595	a	lb/ft	900	1
		b	lb/ft	820	1
TRANSMISSIVITY @ i = 1	ASTM D4716				
and 2000 psf		a	m^2/sec	2.40 x 10^{-3}	4,5
and 10000 psf		a	m^2/sec	1.77 x 10^{-3}	4,5
and 20000 psf		a	m^2/sec	1.26 x 10^{-3}	4,5
COMPRESSION BEHAVIOR					
% retained 10,000 psf	ASTM D1621	a	%	75	2
thickness @ 15,000 psf	ASTM D1621	a	%	70	2
25,000 psf	ASTM D1621	a	%	65	2
RESIN DENSITY	ASTM D1505	a	g/cm³	0.94	
RESIN MELT INDEX	ASTM D1238	a	g/10 min	0.3	
CARBON BLACK CONTENT	ASTM D4218	a	%	0.5	
THICKNESS	ASTM D5199	c	mils	250	3
ROLL WIDTH	-	c	ft	6.7	
ROLL LENGTH	-	c	ft	150 or 200	
ROLL AREA	-	c	ft²	1005 or 1340	
ROLL WEIGHT	-	a	lbs	267 or 363	

QUALIFIERS:
a) Typical value
b) Minimum Average Roll Value
c) Minimum value

NOTES:
1) Tensile properties tested by manufacturer every 5,000 square meters of product as per ASTM D4595 with a specimen width of 8.0 in. and a cross-head speed of 0.40 in./min. in machine direction.
2) Compression behavior tested by manufacturer every 5,000 square meters of product as per ASTM D1621 with a 2 in. by 2 in. specimen and a constant rate of strain of 0.04 in./min.
3) Thickness measured by manufacturer every 5,000 square meters of product as per ASTM D5199 with a 2.22 in. diameter presser foot and 2.9 psi pressure.
4) Transmissivity is calculated as the flow rate per unit width divided by the hydraulic gradient as defined in ASTM D4716.
5) 4831gpm/ft = 1 m^2/sec

TENAX Corporation
4800 East Monument Street
Baltimore, Maryland 21205
(410) 522-7000
fax (410) 522-7015

gnt100 032195

SCHUL INTERNATIONAL

SCHUL INTERNATIONAL COMPANY
5730 OAKBROOK PARKWAY • SUITE 135
NORCROSS, GEORGIA 30093
PHONE (404) 441-0588
FAX (404) 441-0619

UNDERWATER GEL

DESCRIPTION

UNDERWATER GEL is a two component, 100% solids, hydrophillic epoxy gel adhesive. It is a heavy bodied, non-sagging gel that will cure and harden underwater, and once cured, will provide excellent resistance to both fresh and salt water. This product also provides excellent impact and abrasion resistance. This product meets ASTM C-881.

FEATURES

Non-sag gel.
Excellent adhesion.
Abrasion resistant.
Hardens and cures underwater.
High strength.
Impact resistant.
100% solids.
Easy application.

TECHNICAL DATA

	PART A	PART B
Solids	100%	100%
Color	Gray	Gray
Wt./Gal.	12.0 lb.	10.9 lb.
Shelf Life	1 year	1 year

	PROPERTIES	ASTM METHOD
Mix Ratio	1:1 by volume (A:B)	N/A
Viscosity	Non-sagging Gel	N/A
Pot Life (3 oz.) @ 77°F.	40 minutes (standard)	N/A
Hardness (shore) @ 77°F.	75-D	D-2240
Gel Time (5 mil) @ 77°F.	6-8 hours	N/A
Tensile Strength	5,000 psi	D-638
Flexural Strength	3,000 psi	D-790
Compressive Strength	5,000 psi	D-695
Bond Strength	500 psi (24 hours)	C-321
Bond Strength	5125 psi	C-882
Elongation	25%	D-638
Water Absorption	0.25% (24 hours)	N/A

INSTALLATION

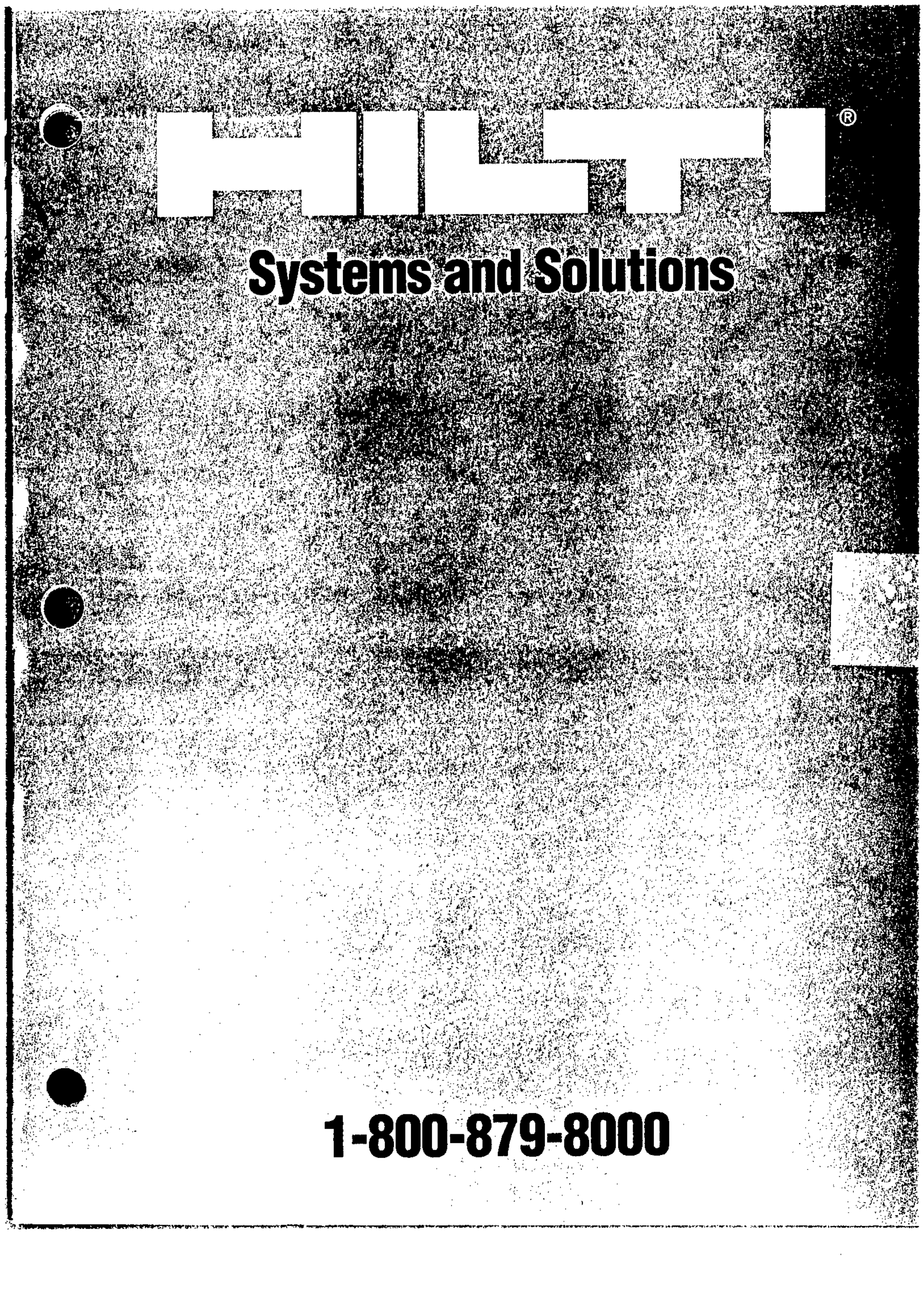
Surface Preparation: Surface of application should be clean and sound. The surface must be free of any dust, oil, grease, laitance, curing compounds, or any other contaminants. This material is intended for use on either steel or concrete surfaces that are constantly or intermittently submerged in fresh or salt water, or in splash zone areas. This may involve pilings, abutments, drainage canals or ditches, drilling rigs, structural supports, well jackets, piping and many other items. When coating is desired to arrest corrosion in splash zone areas, the surface should be cleaned over an area extending from the top of the splash zone to a depth of one to two feet below the low tide level. With other types of treatment, it is a good practice to clean and treat beyond the affected area to provide a positive, watertight seal.

Mixing Procedure: Stir each component separately. Mix 1 part A with 1 part B by volume into a clean mixing container. Mix the epoxy with a slow speed drill with a mixing paddle attachment. Carefully scrape the sides and bottom of the pail during mixing. Blend for 3 minutes. Mix only the amount of material that can be used within the pot life. **Please note: Large batches of epoxy will cure much faster than small batches. Mixed epoxy will cure much faster in hot weather than in cold weather.**

Application: Methods will vary depending upon the job conditions and treatment necessary. For underwater work, the applicator needs a skindiving wet suit, rubber gloves, a life jacket and a life line secured to the structure. Rubber gloves, protective clothing and protective creams are always recommended for all other conditions. Mixed UNDERWATER GEL can be applied by a gloved hand. The average thickness of application should vary between 1/8" and 1/4". The coating is easily molded to the shape or contour of the substrate, provided that the rubber gloves are kept wet. The coating should be applied evenly and uniformly without skips or gaps. Coating application can be initiated by depositing a volume of material immediately above the water line and then working or smearing uniformly up and down over the area to be treated. Feather-edging of all extremities is recommended.

Limitations: Application at ambient or water temperature below 45°F. is not recommended. Where possible, protect treated areas against impact or strong currents for 48 hours. Exposure to temperatures exceeding 150°F. for prolonged periods is not recommended.

ENGINEERED EPOXY SYSTEMS


HILTI®

Systems and Solutions

1-800-879-8000

Expansion Anchor With Unique Wedge Design Satisfies Wide Range Of Fastener Applications

Advantages

- Comprehensive performance testing in concrete, lightweight concrete and grout-filled block base materials
- Enhanced stainless steel anchor performance
- Can be installed in bottomless hole
- Anchor size is same as hole size for easy installation
- Length identification code aids in quality control and inspection *after* installation
- Extra thread length available for double nutting, grout pads and shimming

Anchor Program

- Standard Kwik Bolt II
- Extra Thread Length Kwik Bolt II
- 304SS & 316SS Stainless Steel Kwik Bolt II (All component parts of same stainless steel grade)
- Countersunk Post Nut (Carbon & 304 Stainless Steel)
- Kwik Tie
- Rod Coupling Kwik Bolt II
- Stainless Steel Extra Thread Length
- Custom Special Orders Available in Various Lengths and Materials
- HTN (Hilti Tamper Proof Nut)

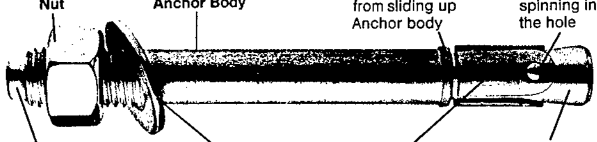
Product Details

Kwik Bolt II anchor sizes range from 1/4" to 1" in diameter and are supplied with washers and nuts or rod couplings

Listings/Approvals

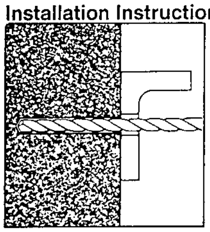
- Meets the description in Federal Specification FF-S-325, Group II, Type 4, Class 1
- UL (Underwriter Laboratories) Listed No. 203, "Pipe Hangers" (3/8" - 3/4" diameters).
- FM (Factory Mutual) Listed "Pipe Hangers" (3/8" KBII with rod coupling)
- ICBO (International Conference of Building Officials) Evaluation Report #4627
- SBCCI (Southern Building Code Congress International) Report #8913
- COLA (City of Los Angeles) Research Report #24946
- Metro-Dade County Approval 93-0224.04

Product Details

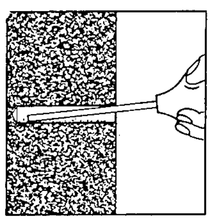


Length Identification Mark

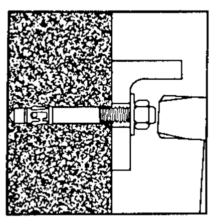
Installation Instructions



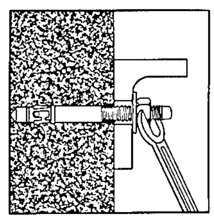
1. Hammer drill a hole the same nominal diameter as the Hilti KWIK BOLT II, with or without the fixture in place–the KWIK BOLT II works in a "bottom-less" hole. Note: hole in baseplate must be 1/16" to 1/8" larger than nominal anchor diameter.



2. Clean hole.



3. Drive the Hilti KWIK BOLT II far enough into the hole so that at least six threads are below the top surface of the fixture. Recommend the Hilti 2 lb. hammer to drive anchor into the concrete.



4. Tighten to the recommended torque value with a torque wrench or, if torque wrench is not available, 2 or 3 turns from the finger tight position to achieve proper anchor setting.

Kwik-Bolt Length Identification System

Stamp on Anchor		A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	V	W	X	Y	Z
Length of Anchor (Inches)	From	1½	2	2½	3	3½	4	4½	5	5½	6	6½	7	7½	8	8½	9	9½	10	11	12	13	14	15	16	17	18
	Up To But Not Including	2	2½	3	3½	4	4½	5	5½	6	6½	7	7½	8	8½	9	9½	10	11	12	13	14	15	16	17	18	19

Stamp on Anchor		AA	BB	CC	DD	EE	FF	GG	HH	II	JJ	KK	LL	MM	NN	OO	PP	QQ	RR	SS	TT	UU	VV	WW	XX	YY	ZZ
Length of Anchor (Inches)	From	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40				
	Up To But Not Including	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41				

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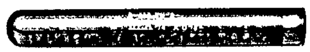
Self-Contained, User Friendly Heavy Duty Anchor System

Advantages

- High load values
- Withstands dynamic and vibratory loading
- Easy-to-use, self-contained adhesive cartridges
- Eliminates guesswork regarding adhesive quantity
- Fast cure time
- Weather resistant

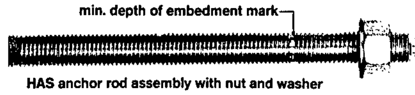
Product Details

The sizes of the HVA Anchor System range from 3/8" to 1 1/4". It is composed of two components which are each sold separately. They are the HEA Capsule and HAS Rod or the HEA Capsule and HFA Insert.

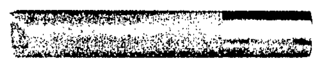


HEA adhesive capsule

min. depth of embedment mark



HAS anchor rod assembly with nut and washer

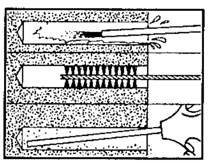


HFA insert

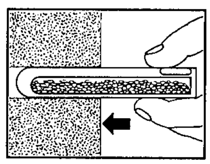
Internally Threaded

The adhesive capsule contains quartz sand, hardening agent and vinylester resin...All self-contained in a glass vial.

Installation Instructions for HAS Rod, HFA and Rebar



1. Set the drill depth gauge and hammer drill the hole to the required hole depth. IMPORTANT: Clean out dust and fragments; preferably using a jet of water, wire brush, and compressed air. The hole may be damp but the standing water should be blown out.



2. Insert appropriate diameter HEA adhesive capsule(s) into pre-drilled hole in base material. At minimum embedment depth, HAS rods and HFA inserts require one adhesive capsule equal in diameter to the nominal thread diameter.

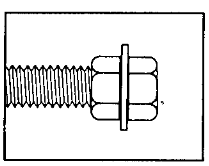
Note: 1 1/4" Hea Capsules should be placed with the metal end cap into the hole.

Recommended Hilti Rotary Hammer Drill

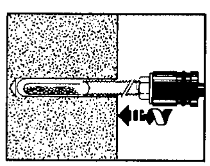
Anchor Size	Drill
3/8"	TE-15, 18M, 24
1/2"	TE-18M, 24, 54, 74
5/8"	TE-18M, 24, 54, 74
3/4"	TE-54, 74, 92
7/8"	TE-54, 74, 92
1"	TE-74, 92
1 1/4"	TE-74, 92

Note:
Neither the TE-74 nor the TE-92 have sufficient power to set 1 1/4" HEA with embedment depths greater than 12". Contact your Field Engineer for details.

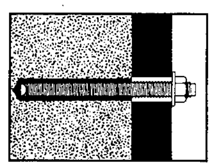
HAS Rod



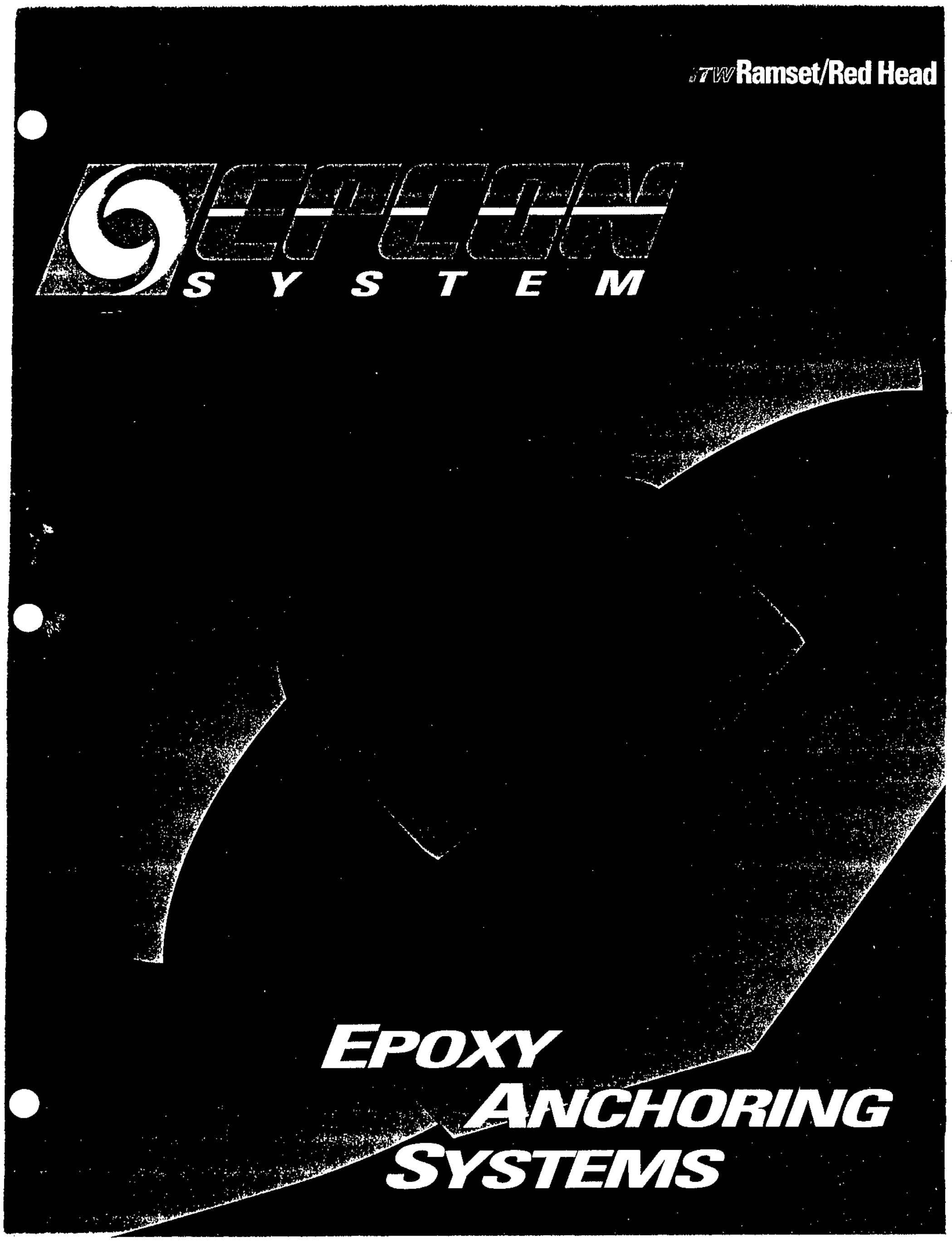
3. HAS
Thread a nut on the HAS rod. Place a washer on top of the first nut and then thread a second nut down on top of the washer. Tighten the two nuts together "locking" the washer between them. The top nut should be flush with the top of the rod.



4. HAS
Insert square drive shaft into hammer drill. Attach proper impact socket. At the rotary hammer drill setting engage the top nut of the HAS rod assembly with the socket and drive the rod in to the embedment mark.



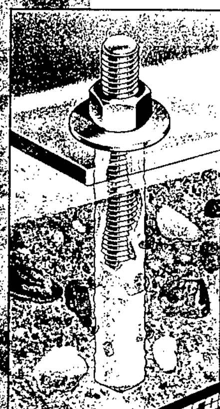
5. HAS
The set anchor rod may not be disturbed or loaded before the end of the specified curing time.


ITW Ramset/Red Head
SYSTEM
EPOXY
ANCHORING
SYSTEMS

EPCON EPOXY ANCHORING SYSTEMS

EPCON SYSTEM

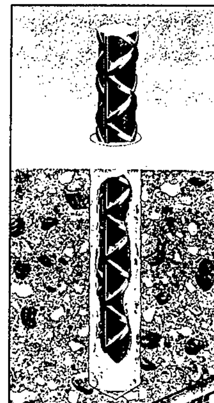
The proprietary formulations for each Epcon System Epoxy are engineered to exhibit consistent performance, provide maximum holding power, and outperform all other systems when anchoring in selected solid concrete and hollow masonry applications.



CERAMIC 6

A unique, ready-to-use, ceramic filled epoxy developed for both solid concrete and hollow block applications. A high-strength, fast cure formulation, Ceramic 6 is perfect for threaded rod, rebar, dowel rod, screens and ESI anchor applications. The epoxy resin and hardener are seperated in a two-chambered cartridge prior to dispensing.

(Part No. E6)



GRANITE 5

Specifically developed for high-strength, low deflection anchor or dowel rod installation in solid concrete, this granite filled slow cure epoxy is ready-to-use. Granite 5 is contained in a two-chambered cartridge that keeps the epoxy resin and hardener seperated until dispensing takes place.

(Part No. G5)

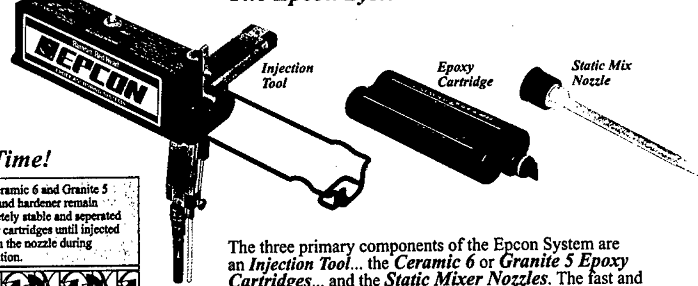
Epcon System Application Guide

	Concrete	Light Weight Concrete	Grout Filled Block	Hollow Block	Solid Brick	Hollow Brick	Thru Fixture	Flush Surface	Temperature Resistant	Dynamic Loading	Leveling Stand-Off	Rebar Doweling	Underwater	Solvent Resistant	Chemical Resistant	Stainless Steel	Galvanized	Zinc Plate	Nylon	Horizontal	Vertical	Overhead	Warm Installation	Cold Installation	Fast Cure	Slow Cure
Ceramic 6	●	●	●	●	●	●	●	●	●	●	●		●	●	○					●	●	●	●	●	●	
Granite 5	●	●	○		●		●		○	●	●	●		●	○					●	●		●			●
Threaded Bar	●	●	●	●	●	●	●		○	●	●		●	○	○	●	●	●		●	●	●				
ESI Insert	●							●	○	●	●		●	○	○	●	●	●		●	●	○				
Screen System			○	●		●				○	○			○	○	●			●	●						

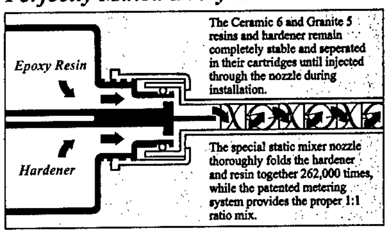
● Very suitable for installation ○ May be suitable depending on application

2

The Epcon System



Perfectly Mixed Every Time!



The three primary components of the Epcon System are an *Injection Tool*... the ***Ceramic 6*** or ***Granite 5 Epoxy Cartridges***... and the ***Static Mixer Nozzles***. The fast and easy operation and simplicity of the system combines the components together to provide maximum job-site performance for any application.

Engineers and Contractors Specify and Use the Epcon System Over Other Systems!

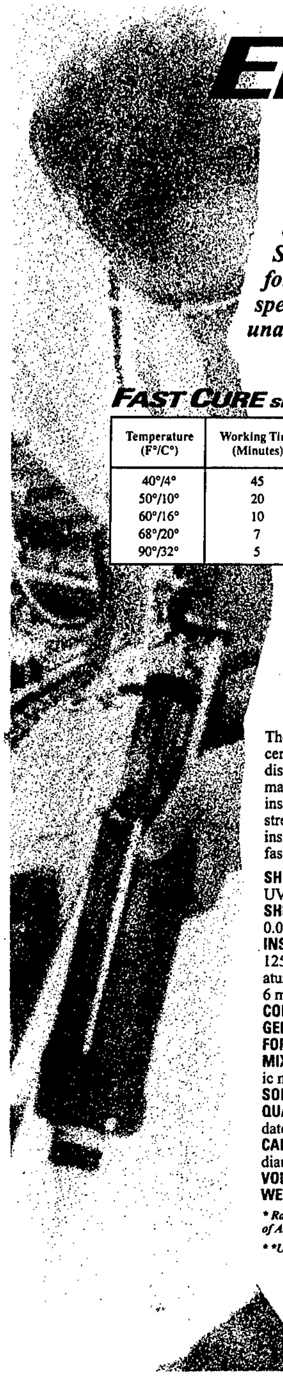
Epcon System Epoxy	GLASS CAPSULES, POLYESTERS, VINYLESTERS & BATCH MIX SYSTEMS
CONSISTENT PERFORMANCE: The special static mixer nozzle thoroughly folds the hardener and resin together 262,000 times, while the patented metering system provides the proper 1-to-1 ratio mix of hardener and Epcon System resin. The result is consistent performance with every anchor installation.	MIXING & PROPORTIONING PROBLEMS: Batch mixed epoxy or polyester misproportioning by as little as 2% to 10%, or not mixing the hardener and resin properly, affects curing and holding strength, and can result in anchor failure.
LONG SHELF LIFE: You can use a portion of a cartridge of Epcon System Epoxy, place it back in stock, and use it 3 years later and get the same product performance. There is no product deterioration, the components remain completely stable and separate until they enter the nozzle.	MATERIAL DEGRADATION: Glass capsules and many polyester and vinylester anchoring systems have a shelf life of less than 1 year, and deterioration increases dramatically in warm temperatures, or if UV light is present.
TREMENDOUS HOLDING POWER: No anchoring system can match the Epcon System Epoxy in overall performance strength. There is no breakdown of bond over time, and tensile performance increases with time.	LOSS OF HOLDING POWER: Vinylesters and polyesters have much lower pullout values, and the chemical bond of these products can break down when exposed to high lime concentrations and moisture.
MINIMUM SHRINKAGE: Epcon System Epoxy shrinks a miniscule 0.00051 in./in. There is no problem with shrinkage leading to dis-bonding in oversized holes.	CONSIDERABLE SHRINKAGE: Polyester and vinylesters shrink, 23 times more than Epcon System Epoxy, resulting in lower holding values.
MINIMUM CREEP: Average deflection of Epcon System Epoxy after 120 days of testing under load was .008 inches. Maximum allowable deflection per ICBO Evaluation testing standards is .015 inches.	ANCHOR MOVEMENT FROM IMPROPER INSTALLATION: Drilling a hole too large, and mixing or proportioning the material improperly can result in anchor creep and anchor failure.
THE EPCON SYSTEM IS SAFE: Contains no styrene or chemical solvents that may pose a possible health threat.	POLYESTERS AND VINYLESTERS CONTAIN STYRENE: Their 40-50% styrene content is a possible health hazard.
HIGH FLASH POINT: Epcon System Epoxy has a 200°F flash point. There is no need to worry about combustibility in warm warehouses.	HIGHLY FLAMMABLE: Polyesters and vinylesters have a flash point as low as 93°F, resulting in material degradation and a possible fire hazard.
EXCELLENT VIBRATORY LOAD PERFORMANCE: Epcon System Epoxy has been tested for 1 million vibratory cycles under various loads without reduction in anchor holding power.	NO PERFORMANCE DATA: No published data has been found on polyester and vinylester vibratory load performance.
MATERIAL COST SAVINGS: The Epcon System Epoxy Anchoring System is designed to provide a specific, accurate, pre-measured amount of material with every installation. There is no waste, keeping material costs down.	WASTED MATERIAL: Polyesters and vinylesters set up in less than a few minutes in hot weather, resulting in hardened material, waste, and costly time loss.
UNDERWATER INSTALLATION: Epcon System Epoxy can be installed under fresh or salt water with minimal reduction of holding power, and as submersion tests show, there is minimal reduction over time.	SENSITIVE TO MOISTURE: Polyesters and vinylester anchoring systems are sensitive to moisture, and may debond and fail.
EXCELLENT WETTING CHARACTERISTICS: Epcon System Epoxy thoroughly wets and bonds with the surface of the hole. It can be used in a core-drilled hole with no loss of strength.	POOR BONDING: Polyesters and vinylesters have poor wetting characteristics. The hole must be rough for a good bond, and the manufacturers do not recommend using a core-drilled hole.

3

EPCON
EPOXY ANCHORING SYSTEMS

EPOXY FORMULAS

Bo[illegible] Ep[illegible] developed to provide maximum performance and high-strength holding power for hundreds of demanding anchoring applications. Epcon System epoxies offer, with fast and slow cure formulations, contractors, engineers, and specifiers high-quality anchoring performance unavailable from any other manufacturer.



FAST CURE SETTING TIME FOR CERAMIC 6

Temperature (F°/C°)	Working Time (Minutes)	Loading Time (Hours)	Torque-Up Time (Hours)	Full Cure Time (Hours)
40°/4°	45	3	5	48
50°/10°	20	2	4	36
60°/16°	10	1.5	3.5	24
68°/20°	7	1	3	24
90°/32°	5	1	3	24

At temperatures between 40°F-50°F, Ceramic 6 should be heated to room temperature or up to 150°F maximum (use Heater Box #EH1000 or Cartridge Heater #EF1000) to Improve product flow and assure proper curing.

C6

(Part No. E6)

The Ceramic 6 Formula is comprised of a proprietary ceramic-filled epoxy resin and hardener, injection dispensed from a two-chambered cartridge designed to maintain separate integrity of the components until installation takes place. Specifically designed for high-strength, low deflection anchor, doweling or rebar installation in solid concrete, hollow block, or brick fastening.

SHELF LIFE: 3 years minimum, not sensitive to heat or UV light.
SHRINKAGE DURING CURE: Per ASTM D2566- 0.00051 in./in.
INSTALLATION TEMPERATURE LIMIT: Substrate 40°F to 125°F (4°C to 52°C). Note: If anchor installation temperature conditions are below substrate minimum, Ceramic 6 must be warmed prior to installation.
COMPRESSIVE STRENGTH: Per ASTM-C39, 12,067 psi.
GEL TIME: 7 to 60 minutes.
FORMULATION COLOR: Concrete grey.
MIXTURE RATIO: 1:1 by volume, resin to hardener, (static mix injection).
SOLVENTS: None.
QUALITY CONTROL: All production formulations are date coded and application tested.
CAPACITY: Per ASTM 615 (deformed bar) at 12 bolt diameters embedment (predictable failure).
VOLUME: 17.9 fl.oz. (530ml, 530cc, 32.3cu.in.).
WEIGHT: 1.78 lbs. (0.807 Kg).

** Ramset/Red Head Ceramic 6 epoxy meets the physical requirements of ASTM C881-90 Type IV Grade 3 epoxy.*

***Use with Epcon EH1000, EF1000 heating systems.*

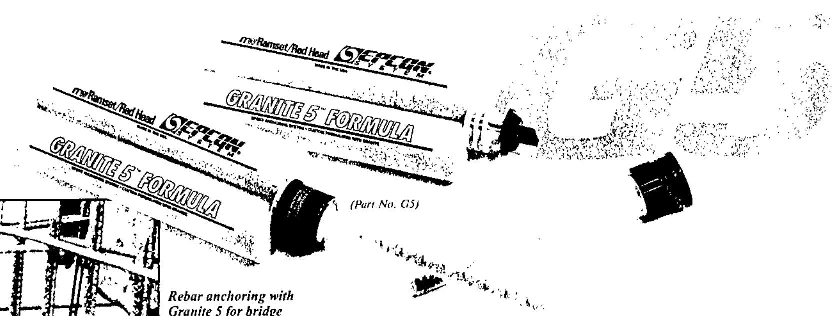
FEATURES

- *Solid Concrete, Hollow Block, or Brick Applications*
- *Ceramic Filled*
- *Ready-to-Use*
- *Fast Cure*
- *Minimum Deflection Under Load*
- *High Load Capacity*
- *Minimum Shrinkage*
- *Underwater Installation*
- *Potable Water Applications*
- *High-Temperature Resistance*
- *Vibration Resistance*
- *Cold Temperature Application***

I.C.B.O. LISTED
ER #4285

Ceramic 6 for high-strength overhead applications.

4



(Part No. G5)

Rebar anchoring with Granite 5 for bridge pier reinforcements.

Granite 5 is ideal for general construction.

SLOW CURE SETTING TIME FOR GRANITE 5

Temperature (F°/C°)	Working Time (Minutes)	Loading Time (Hours)	Torque-Up Time (Hours)	Full Cure Time (Hours)
40°/4°	68	12	36	48
50°/10°	60	10	29	36
60°/16°	50	5	20	24
68°/20°	45	4	18	24
90°/32°	34	4	17	24

At temperatures between 40°F-50°F, Granite 5 should be heated to room temperature or up to 150°F maximum (use Heater Box #EH1000 or Cartridge Heater #EF1000) to improve product flow and assure proper curing.

Anchoring highway sign trusses with Granite 5.

FEATURES

- *Granite Filled*
- *Slow Cure*
- *Odorless*
- *Long Nozzle Life*
- *Moderate Temperature Deflection*
- *High Load Capacity*
- *Minimum Shrinkage*
- *Large Diameter Hole and Deep Hole Applications*
- *Vibration Resistance*

The Granite 5 Formula is a granite-filled, Amine Base Epoxy, injection dispensed to a smooth, non-sag consistency. The product is contained in a two-chambered cartridge which keeps the epoxy resin and hardener components separated until dispensing takes place. Specifically designed for high-strength, low deflection anchor, doweling and rebar installation in solid concrete construction fastening applications.

SHELF LIFE: 2 years minimum, not sensitive to heat or UV light.
SHRINKAGE DURING CURE: Per ASTM D2566-0.00004 in./in.
INSTALLATION TEMPERATURE LIMIT: Substrate 40°F to 125°F (4°C to 52°C). Note: If anchor installation temperature conditions are below substrate minimum, Granite 5 must be warmed prior to installation.
COMPRESSIVE STRENGTH: Per ASTM-D695 (with 1/2" cube), 9,170 psi.
GEL TIME: 45 minutes.
FORMULATION COLOR: Concrete tan.
MIXTURE RATIO: 1:1 by volume, resin to hardener, (static mix injection).
SOLVENTS: None, 100% odorless.
QUALITY CONTROL: All production formulations are date coded and application tested.
CAPACITY: Per ASTM 615 (deformed bar) at 12 bolt diameters embedment (predictable failure).
VOLUME: 17.9 fl.oz. (530ml, 530cc, 32.3cu.in.).
WEIGHT: 1.78 lbs. (0.807 Kg).

** Ramset/Red Head Granite 5 epoxy meets the physical requirements of ASTM C881-90 Type II Grade 3 epoxy.*

Ceramic 6 used in fascia bracket installation.

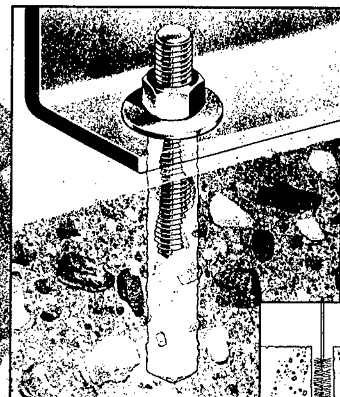
Vibration resistance of Ceramic 6 is perfect for concrete tie repairs.

5

EPCON
EPOXY ANCHORING SYSTEMS

INSTALLATION

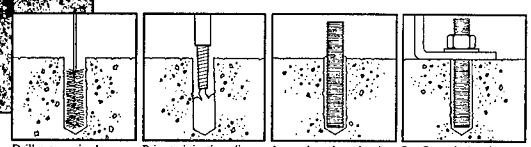
Threaded rods, dowel rods, or rebar each require high-strength holding power to provide optimum performance. Solid concrete and hollow block applications require specific installation procedures, as well as epoxy formula choices for applications.



SOLID CONCRETE

Ceramic 6 and Granite 5 Epoxy perform effectively in both rotary hammer and core drilled holes. The anchor stud (*threaded rod, rebar, or dowel rod*) must be clean of dirt, dust, paint, grease, oil, rust or other contamination or coating which would prevent direct epoxy adhesion.

In ceiling and wall applications, insert a proper sized Hole Plug (*see page 12*) into the hole opening. Insert nozzle through cross cut opening and fill hole approximately half full. Granite 5 is not recommended for overhead applications.



Drill proper sized hole. Clean out hole with blowout-bulb or the blow- out hose attached to the E200 or E300 injector tools. Complete hole preparation with use of a nylon brush (*do not use wire brush*).

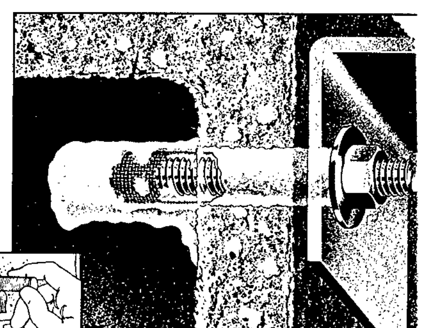
Prior to injection, discharge approximately one fluid ounce of epoxy. **Match color on the instruction card included**. Insert the nozzle into the bottom of the hole, and fill to 1/2 the hole depth.

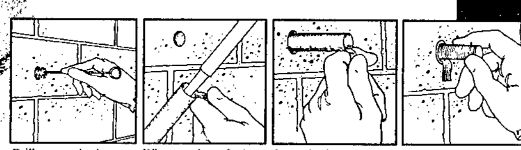
Insert the selected rod slowly by hand into the bottom of the hole with a slow twisting motion. This insures the epoxy fills voids and crevices.

See Ceramic 6 and Granite 5 Cure Time Charts for set-up time. After the recommended cure time is met (*charts on pages 4 and 5*), install and tighten fixture into place.

HOLLOW BLOCK

Follow the same drilling and hole preparation steps as in the Solid Concrete installation guidelines. Ceramic 6 Epoxy anchors installed in hollow block or brick walls require the use of Epcon System stainless steel or nylon screens (*see page 12 for size information*). Granite 5 is not recommended for hollow block applications.





Drill proper sized hole. Clean out hole with blowout-bulb or the blow- out hose attached to the E200 or E300 injector tools. Complete hole preparation with use of a nylon brush (*do not use wire brush*).

When starting a fresh cartridge, discharge approximately one fluid ounce, as in the instructions above. Insert the nozzle to bottom of screen and fill completely while withdrawing the nozzle.

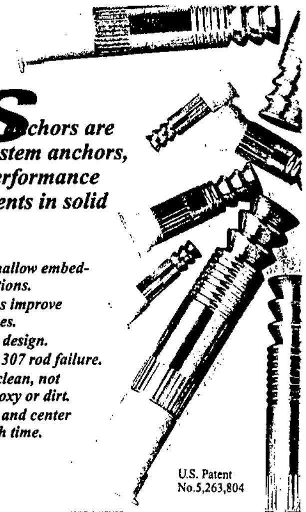
Insert the filled screen completely into the cleaned hole.

While holding the tab of the screen against the wall, hand insert the selected rod slowly into the screen tube with a slow twisting motion. Wait for appropriate cure time before torquing fixture in place (*see Ceramic 6 Chart on page 4*).

NEW!

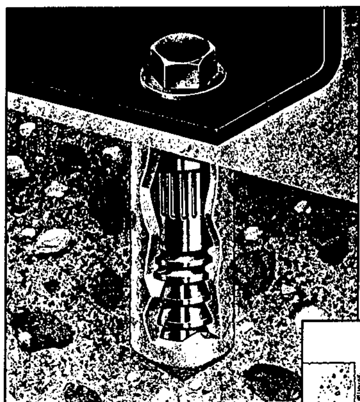
Epcon System Nylon Screens Available in 3/8" and 1/2" diameters; 6",8", and 10" lengths. Special lengths available.

6



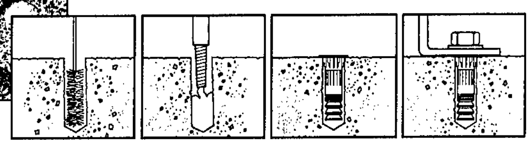
ESI ANCHORS

Epcon System Insert (ESI) Anchors are internally threaded epoxy system anchors, engineered to provide high performance anchoring at shallow embedments in solid concrete applications.



- ***Available in five sizes, with polyethylene cap and/zinc plate or stainless steel body.***
- ***Cap configuration centers bolt in ESI.***
- ***Anchor configuration centers ESI in hole.***
- ***Close to edge installation.***
- ***Can be removed and reinserted.***
- ***High load, shallow embedment applications.***
- ***Annular rings improve pull-out values.***
- ***Anti-rotation design.***
- ***Predictable A307 rod failure.***
- ***Threads are clean, not exposed to epoxy or dirt.***
- ***Proper depth and center achieved each time.***

U.S. Patent No.5,263,804



Drill proper sized hole (*see selection chart*). Clean out hole with blowout-bulb and/or compressed air. Complete hole preparation with use of a nylon brush (*do not use wire brush*).

Prior to injection, discharge approximately one fluid ounce of epoxy. **Match color on the instruction card included.** Insert the nozzle into the bottom of the hole, and fill to 1/2 the hole depth.

Insert ESI anchor in a slow twisting motion by hand until the top of the anchor is flush with base material.

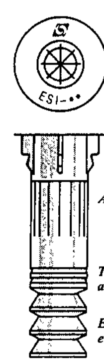
After recommended cure time (*see Ceramic 6, page 4*), with hand, push threaded rod through center to engage internal threads. A minimum of three threads is needed for proper load requirement. Install and tighten fixture.

Epcon System Insert (ESI) Selection Guide

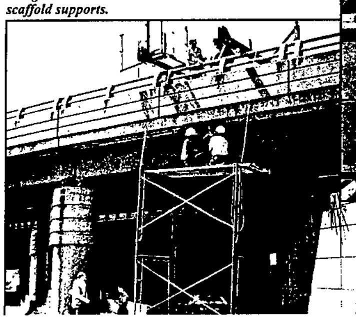
Part No.	Hole Size (Inch)	Hole Depth (Inch)	Bolt Size/Threads Per Inch	Thread Depth	Ultimate Load (Lbs.)*		Torque Setting (Ft-Lbs.)	Anchors Per E6 Cartridge	ASTM A307 Grade A Steel Strength (Lbs.)
					Tension	Shear			
ESI-14	7/16	1-3/4	1/4-20 UNC	1/2"	1975	3171	5	160	1900
ESI-38	3/4	2-1/2	3/8-16 UNC	3/4"	7318	7783	18	48	4650
ESI-12	7/8	3-3/8	1/2-13 UNC	1"	10517	14221	42	28	8500
ESI-58	1	4-1/2	5/8-11 UNC	1-1/4"	14839	22612	84	16	13550
ESI-34	1-1/8	5-1/2	3/4-10 UNC	1-1/2"	23741	33505	150	12	20050

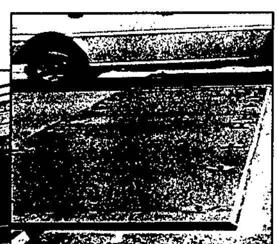
** Contact technical services for overhead applications and shear application data.*

High Capacity/Shallow Embedmen



Bridge conduit and scaffold supports.





High load temporary bridge repair plates.

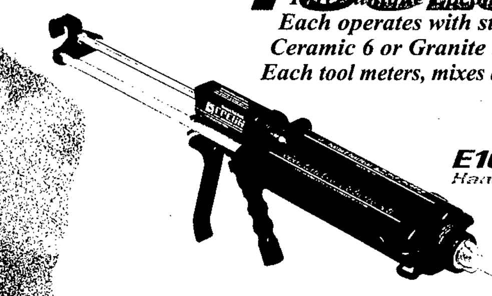
7

EPCON

EPOXY ANCHORING SYSTEMS

INJECTION TOOLS

Three unique Epcon Injection Tools are available. Each operates with standard Epcon System Ceramic 6 or Granite 5 cartridges and nozzles. Each tool meters, mixes and injects the epoxy formulas.

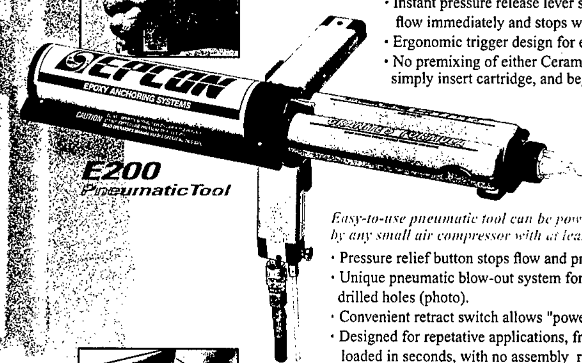


E101
Hand Tool

E24 Nozzle

Lightweight, compact steel construction of this hand-operated tool allows for fast, easy efficient anchor installation and epoxy injection.

- Fast loading and easy to operate.
- Instant pressure release lever shuts down epoxy flow immediately and stops waste.
- Ergonomic trigger design for ease of use.
- No premixing of either Ceramic 6 or Granite 5 formulas, simply insert cartridge, and begin pumping.



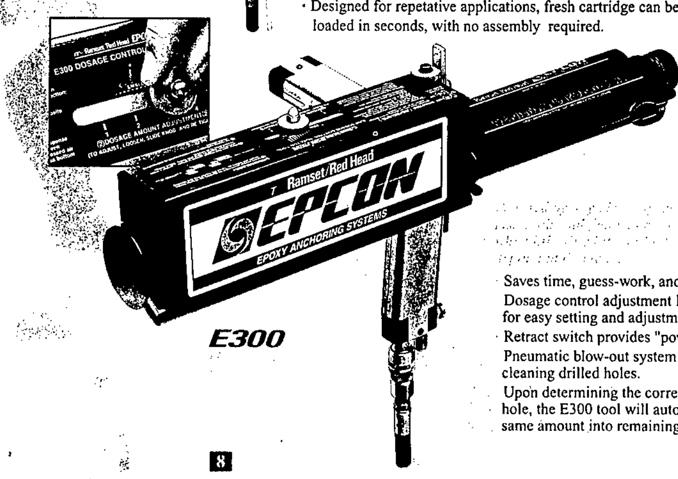
E200
Pneumatic Tool

E24 Nozzle

Easy-to-use pneumatic tool can be powered by any small air compressor with at least 60 p.s.i.

- Pressure relief button stops flow and prevents dripping and waste.
- Unique pneumatic blow-out system for automatically cleaning drilled holes (photo).
- Convenient retract switch allows "power return" of E200 pistons.
- Designed for repetative applications, fresh cartridge can be loaded in seconds, with no assembly required.

E50 Nozzle



E300

- Saves time, guess-work, and prevents waste.
- Dosage control adjustment located on top of tool for easy setting and adjustment (photo).
- Retract switch provides "power return" of pistons.
- Pneumatic blow-out system for automatically cleaning drilled holes.
- Upon determining the correct dosage in the first hole, the E300 tool will automatically inject the same amount into remaining holes.

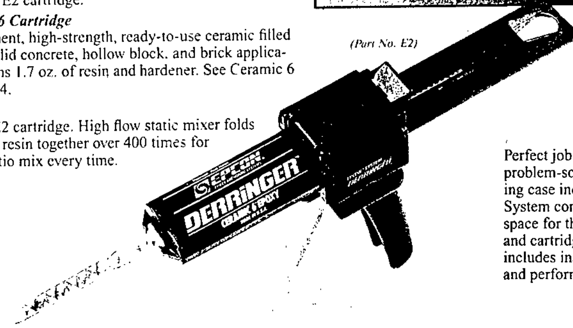
8

DERRINGER

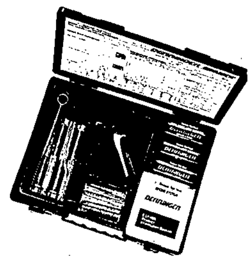
E400 Tool
Small and compact, made of high-strength impact-resistant engineered plastic. Ideal on scaffolds or tight spaces where heavier more cumbersome tools are difficult to handle. Designed for E2 cartridge.

E2 Ceramic 6 Cartridge
Dual component, high-strength, ready-to-use ceramic filled epoxy. For solid concrete, hollow block, and brick applications. Contains 1.7 oz. of resin and hardener. See Ceramic 6 data on page 4.

E12 Nozzle
Attaches to E2 cartridge. High flow static mixer folds hardener and resin together over 400 times for proper 1:1 ratio mix every time.



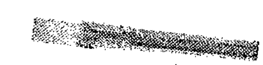
(Part No. E2)



Perfect job-site anchor installation problem-solving kit. Sturdy carrying case includes various Derringer System components, additional space for threaded rods, screens, and cartridges. Inside lid chart includes installation instructions and performance information.

ACCESSORIES

The Epcon System is complemented by a complete line of accessories, designed to contribute to maximum anchoring performance for each installation.



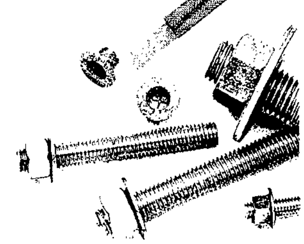
Lightweight heater box is electrically powered to heat twelve Ceramic 6 or Granite 5 cartridges on the jobsite. Self-contained heater unit provides constant source of epoxy availability at cold temperature applications.

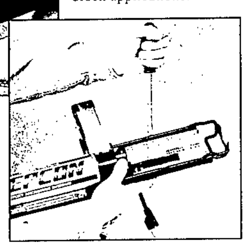
EPCON SYSTEM ACCESSORIES

Threaded Rods
Available in 8 diameters (1/4"-1 1/4"); fully threaded; zinc plated; nuts and washers included. Special lengths, stainless steel available.

Stainless Steel Screens
Available in 6 diameters and 4 lengths for hollow block applications. For maximum corrosion protection.

Nylon Screens
Available in 2 diameters and 3 lengths for hollow block applications.





Easy-to-attach individual cartridge (Ceramic 6 or Granite 5) heater is electrically powered to heat epoxy to required working temperature at cold temperature jobsites. Fits E101, E200, or E300 installation tools.

Heater Box
Holds twelve Ceramic 6 or Granite 5 cartridges.

Cartridge Heater
Individual heating unit attachs to E101, E200, or E300 tools to heat cartridge.

Hole Plugs
Seven sizes available for overhead solid concrete applications.

Nozzle Extension Tubes
Extension tube attaches to E24 or E50 nozzles for deep hole installations. (*Available in 25 foot roles. Cut to meet individual job requirements.*)

Contact your authorized Epcon System Distributor for the complete line of accessories available. See pages 11 and 12 for threaded rod, screens, hole plug sizes and part numbers.

9

EPCON
EPOXY ANCHORING SYSTEMS

SPECIFICATIONS

CERAMIC 6

Approvals/Listings

- I.C.B.O. ES Listing–Report #4285
- City of Los Angeles General Construction Approval–RR #24975
- City of Los Angeles Unreinforced Masonry Approval (Seismic)–RR #24927
- ASTM C881-90 Type IV Grade 3 epoxy*
- AASHTO M235-90 Type III Grade 3

*Contact Ramset/Red Head engineering department for details/exceptions.

Ceramic 6 Setting Time

Temperature (F°/C°)	Working Time (Minutes)	Loading Time (Hours)	Torque-up Time (Hours)	Full Cure Time (Hours)
40°/4°	45	3	5	48
50°/10°	20	2	4	36
60°/16°	10	1.5	3.5	24
68°/20°	7	1	3	24
90°/32°	5	1	3	24

At temperatures below 40°F, Ceramic 6 Epoxy should be heated to room temperature or up to 150°F (heater frame or heater box) to improve product flow and assure proper curing.

*Ceramic 6 Performance in Grout Fill Block (CMU)**

Anchor Diameter	Hole Diameter	Embedment Depth	Ultimate Tension (Lbs.)
3/8"	7/16"	3"	4862
1/2"	5/8"	3"	4953
1/2"	5/8"	6"	8214

*Block = ASTM C90, Grade N, 1000 PSI minimum.
Grout = ASTM C476, 2000 PSI minimum.

Average Ultimate Loads for Ceramic 6 Epoxy Threaded Rod Anchors*[1]

Anchor Dia.	Hole Dia.	Embed-ment**	2000 psi Concrete Tension (Lbs)	2000 psi Concrete Shear (Lbs)	3500 psi Concrete Tension (Lbs)	3500 psi Concrete Shear (Lbs)	6000 psi Concrete Tension (Lbs)	6000 psi Concrete Shear (Lbs)	Tightening Torque (Ft.-lbs.)	No. of Anchors per E2 Cartridge	No. of Anchors per E6/G5 Cartridge
1/4"	5/16"	1" 2-1/4" 3"	— — —	— — —	1653 2818 3599	— — —	— — —	— — —	3-5	41 18 13	418 180 133
3/8"	7/16"	1-1/2" 3-3/8" 4-1/2"	— 6660 —	— 5085 —	3426 8567 10603	— 6009 —	— 10621 —	— 5941 —	13-18	16 7 5.5	162 72 55
1/2"	9/16"	2" 4-1/2" 6"	— 11308 —	— 8854 —	6100 14499 17410	— 8801 —	— 13905 —	— 10603 —	22-25	9 4 3	90 40 30
5/8"	3/4"	2-1/2" 5-5/8" 7-1/2"	— 16770 —	— 13163 —	8775 22880 29456	— 16458 —	— 24194 —	— 17089 —	55-80	4 2 1.3	40 18 13.5
3/4"	7/8"	3" 6-3/4" 9"	— 29667 —	— 15982 —	12625 32860 38865	— 20347 —	— 33759 —	— 24482 —	106-160	2.6 1.2 .9	26 12 9
7/8"	1"	3-1/2" 7-7/8" 10-1/2"	— 35257 —	— 21548 —	18650 37714 51211	— 30295 —	— 41023 —	— 32573 —	185-250	1.9 0.8 0.6	18.5 8 6
1"	1-1/8"	4" 9" 12"	— 43306 —	— 25236 —	25034 45608 63053	— 38026 —	— 44835 —	— 46416 —	276-330	1.4 0.6 0.5	14 6 5
1-1/4"	1-3/8"	5" 11-1/4" 15"	— — —	— — —	37100 53000 64925	— — —	— — —	— — —	370-660	0.8 0.4 0.3	8.4 3.7 3

*Safe working loads for individually installed anchors under static loading conditions should not exceed 25% of anchor's ultimate load capacity.
**Shallower embedments can be used, but values will be lower than shown, job site test as needed.
[1]Performance values are based on the use of high strength threaded rod.

GRANITE 5

Approvals/Listings

- Contact technical service for approvals and listings obtained for state D.O.T.'s.
- Ramset/Red Head Granite 5 epoxy meets the physical requirements of ASTM C881-90 Type II Grade 3 epoxy*

*Contact Ramset/Red Head engineering department for details/exceptions.

Granite 5 Setting Time

Temperature (F°/C°)	Working Time (Minutes)	Loading Time (Hours)	Torque-up Time (Hours)	Full Cure Time (Hours)
40°/4°	68	12	36	48
50°/10°	60	10	29	36
60°/16°	50	5	20	24
68°/20°	45	4	18	24
90°/32°	34	4	17	24

At temperatures between 40°F-50°F, epoxy should be heated to room temperature or up to 150°F maximum (use heater box #EH1000) to improve product flow and assure proper curing

Average Ultimate Loads for Granite 5 Epoxy Rebar Anchor

Rebar Dia.	Hole Dia.	Embedment	Anchors Per G5 Cartridge	3500 psi Concrete** Tension (Lbs.)	3500 psi Concrete** Shear (Lbs.)
#3	1/2"	4-1/2"	53	9770	6600
#4	5/8"	6"	32	16514	12000
#5	3/4"	7-1/2"	21	32025	18600
#6	7/8"	9"	14	34063	26400

Tests were performed using Grade 60 reinforced bar.
***Performance values reflect epoxy's ultimate strength. Safe working loads should not exceed 25%. Load values must be based on epoxy bond strength or steel yield value, whichever is lessor.*

Average Ultimate Loads for Granite 5 Epoxy Threaded Rod Anchors

Anchor Dia.	Hole Dia.	Embedment	Anchors Per G5 Cartridge	3500 psi Concrete** Tension (Lbs.)	3500 psi Concrete** Shear (Lbs.)
1/4"	5/16"	2-1/4"	180	2790	2494
3/8"	7/16"	3-3/8"	72	8395	6009
1/2"	9/16"	4-1/2"	40	14064	8801
5/8"	3/4"	5-5/8"	18	20664	16458
3/4"	7/8"	6-3/4"	12	32531	20347

Tests were performed using B7 rod

Ceramic 6 Hollow Wall Anchor Selection Chart

Threaded Rod Diameter (In)	Cat. No.[1] Anchor Screen	Screen Length[2] (In)	Hole Diameter (In)	Torque Ft./lbs. (Max)
1/4	HB14-2	2	3/8	6
3/8	HB38-312	3-1/2	1/2	9
3/8	HB38-6	6	1/2	7
3/8	HB38-8	8	1/2	16
3/8	HB38-10	10	1/2	16
1/2	HB12-312	3-1/2	5/8	14
1/2	HB12-6	6	5/8	17
1/2	HB12-8	8	5/8	26
1/2	HB12-10	10	5/8	26
5/8	HB58-412	4-1/2	3/4	18
5/8	HB58-6	6	3/4	21
5/8	HB58-8	8	3/4	39
5/8	HB58-10	10	3/4	39
3/4	HB34-10	10	7/8	38
3/4	HB34-13	13	7/8	38

[1] Anchor screens are sized to fit the threaded rod used and require a hole diameter 1/8" larger than the rod's nominal size. Example: The HB12-8 anchor screen uses a 1/2" diameter threaded rod (embedded 8") and is installed in a 5/8" diameter hole.
[2] Other special lengths available (some restrictions apply).

Average Ultimate Loads for Ceramic 6 Epoxy Rebar Anchor[1]*

Anchor Dia.	Drill Bit Dia.	Embed-ment**	2500 psi Concrete		3500 psi Concrete	
			Tension (Lbs)	Shear (Lbs)	Tension (Lbs)	Shear (Lbs)
#3	1/2"	3-3/8	7592	6277	–	–
#3	1/2"	4-1/2	–	–	9800	–
#4	5/8"	4-1/2	11303	9735	–	–
#4	5/8"	6	–	–	16720	–
#5	3/4"	5-5/8	14167	15526	–	–
#5	3/4"	7-1/2	–	–	33000	–
#6	7/8"	6-3/4	28779	20442	–	–
#6	7/8"	10	–	–	45000	–
#7	1-1/8"	13	–	–	65300	–
#8	1-1/4"	16	–	–	86700	–
#9	1-1/2"	19	–	–	108000	–
#10	1-1/2"	19	–	–	120000	–

**Safe working loads for individually installed anchors under static loading conditions should not exceed 25% of anchor's ultimate load capacity.*
***Shallower embedments can be used, but values will be lower than shown, job site test as needed.*
[1] Tests were performed using Grade 60 performed reinforcing bar.

Ceramic 6 Performance in Single and Double Wall Hollow Block

Threaded Rod Diameter (In)	Hollow Block		No. of Anchors per E2 Cartridge							No. of Anchors per E6 Cartridge						
			Screen Length							Screen Length						
	Ultimate Tension (Lbs)	Ultimate Shear (Lbs)	2"	3-1/2"	4-1/2"	6"	8"	10"	13"	2"	3-1/2"	4-1/2"	6"	8"	10"	13"
1/4	1550*	1900*	12							126						
3/8	1661*	3340*		5							48					
3/8	1333*	2620*				2							24			
3/8	2803**	2953**					2	1						19	15	
1/2	1873*	2242*		3							28					
1/2	2213*	3300*			1.5	2							17			
1/2	3487**	2668**					1	1						12	9	
5/8	1970*	3554*			1.5							16				
5/8	2213*	2367*				1							12			
5/8	4217**	3578**					1	.75						9	7	
3/4	3410**	4573**						.4	.3						4.25	3.75

**Tested in single wall of hollow block.* ***Tested in double wall of hollow block (longest screen).*

ACCESSORIES

Epcon System Threaded Rod Selection Chart

Anchor Dia.	THREADED ROD		Hole Plug (Overhead Use)
	Catalog No.*	Description	
1/4"	STR14-212 (Stainless)	1/4" x 2-1/2"	–
3/8"	TR38-512 TR38-612 TR38-8 TR38-12	3/8" x 5-1/2" 3/8" x 6-1/2" 3/8" x 8" 3/8" x 12"	E038
1/2"	TR12-512 TR12-612 TR12-8 TR12-12	1/2" x 5-1/2" 1/2" x 6-1/2"1 1/2" x 8" 1/2" x 12"	E012
5/8"	TR58-8 TR58-912 TR58-12	5/8" x 8" 5/8" x 9-1/2" 5/8" x 12"	E058
3/4"	TR34-834 TR34-11 TR34-13 TR34-16	3/4" x 8-3/4" 3/4" x 11" 3/4" x 13" 3/4" x 16"	E034
7/8"	TR78-10 TR78-1212	7/8" x 10" 7/8" x 12-1/2"	E078
1"	TR1-11 TR1-14	1" x 11" 1" x 14"	E010
1-1/4"	TR114-1314 TR114-17	1-1/4" x 13-1/4" 1-1/4" x 17"	E114

**Catalog numbers shown reflect stocked full-threaded stud in zinc plated low carbon steel (A307) unless otherwise noted. Nuts and washers are included. Also available on a special order basis in high strength carbon steel, stainless steel, or in special lengths. If any steel certification is required a special order is to be placed with Customer Service*

Carbide Bit Selection Guide for Rebar

Rebar		Hole Dia.	Embedment Depth	Spline Bit No.	SDS Bit No.
Size	Dia.				
#3	3/8"	1/2"	4-1/2"	DSS-126	DD-1210
#4	1/2"	5/8"	6"	DSS-586	DD-586
#5	5/8"	3/4"	7-1/2"	DSS-3412	DD-3410
#6	3/4"	7/8"	10"	DSS-7812	DD-7810
#7	7/8"	1-1/8"	13"	DSS-11818	–
#8	1"	1-1/4"	16"	DSS-11418	–
#9	1-1/8"	1-1/2"	18"	–	–
#10	1-1/4"	1-1/2"	19"	–	–

Carbide Bit Selection Guide for Threaded Rod

Threaded Rod Dia.	Hole Dia.	Embedment Depth	Spline Bit No	SDS Bit No.
1/4"	5/16"	3"	–	DD-5164
3/8"	7/16"	4-1/2"	DSS-7166	–
1/2"	9/16"	6"	DSS-9168	–
5/8"	3/4"	7-1/2"	DSS-3412	DD-3410
3/4"	7/8"	9"	DSS-7812	DD-780
7/8"	1"	10-1/2"	DSS-118	DD-116
1"	1-1/8"	12"	DSS-11818	–
1-1/4"	1-3/8"	15"	DSS-13818	–

EPCON
EPOXY ANCHORING SYSTEMS

ACCESSORIES

Injection Tools

Catalog No.	Epcon Power	Cartridge	Nozzle
E101	Manual	E6/G5	E24, E50
E200	Pneumatic	E6/G5	E24, E50
E300	Pneu. Dosage Control	E6/G5	E24, E50
E400	Manual	E2	E12

Epoxy Cartridges

Catalog No.	Volume	Nozzle	Tool
E6	17.9 Fl. Oz.	E24, E50	E101, E200, E300
E2	1.7 Fl. Oz.	E12	E400
G5	17.9 Fl. Oz.	E24, E50	E101, E200, E300

Injection Nozzles

Catalog No.	Outside Diameter	Cartridge	Tool
E12	3/8"	E2	E400
E24	1/2"	E6/G5	E101, E200, E300
E50	11/16"	E6/G5	E101, E200, E300

Nylon Screen Selection Guide

Part No.	Screen Length	Anchor Diameter	Drill Bit Diameter
HBP38-6	6"	3/8"	1/2"
HBP38-8	8"	3/8"	1/2"
HBP38-10	10"	3/8"	1/2"
HBP12-6	6"	3/8"	5/8"
HBP12-8	8"	3/8"	5/8"
HBP12-10	10"	3/8"	5/8"

Accessories

Catalog No.	Description
E25	Nozzle Extension Tubing (25')
800063	Steel Tool Case (E101)
800064	Steel Tool Case (E200, E300)

Nylon Brushes

Catalog No.	Dia.
B012	1/2"
B034	3/4"
B100	1-0"
B114	1-1/4"
B112	1-1/2"

Hole Plug Selection Guide

Part No.	Rod Diameter	Drill Bit Diameter
E038	3/8"	7/16"
E012	1/2"	9/16"
E058	5/8"	3/4"
E034	3/4"	7/8"
E078	7/8"	1"
E010	1"	1-1/8"
E114	1-1/4"	1-3/8"

WARRANTY AND REMEDY
All warranties of the products described herein, expressed or implied, including the warranties of merchantability and fitness for particular purposes are specifically excluded, except for the following: ITW Ramset/Red Head will repair or replace at its sole option any tool part, or fastener which within twelve months after sale by ITW Ramset/Red Head or its distributors, is found by ITW Ramset/Red Head to be defective in material or workmanship, normal wear and tear excluded.
This is the sole warranty of ITW Ramset/Red Head and the sole remedy available to distributor or buyer.

LIMITATION OF LIABILITY
ITW Ramset/Red Head shall not be liable for any injury, loss or damage, direct, indirect, incidental or consequential, arising out of the use of, or the inability to use, the products described herein.

CAUTION
Failure to follow proper safety and installation procedures can result in serious personal injury or property damage.

MADE IN USA

ITW Ramset/Red Head

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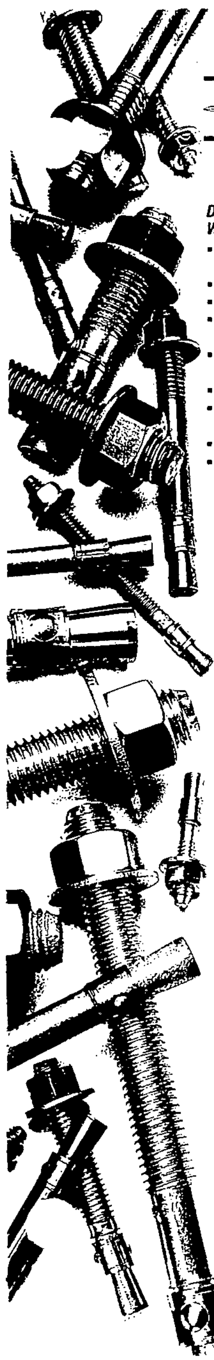
Patents Pending
Printed in U.S.A.

STAFDA ASSOCIATE

EGC/3-94



ITW Ramset/Red Head

RED HEAD
CONCRETE ANCHORING SYSTEMS

MADE IN U.S.A.

TRUBOLT WEDGE

DEPENDABLE, HEAVY DUTY, INSPECTABLE, WEDGE TYPE EXPANSION ANCHOR

- ***Versatile fully threaded design is standard on sizes up to ¾" diameter and 7" length.***
- Anchor diameter equals hole diameter.
- One piece stainless steel expander clip resists corrosion.
- 360° contact with concrete assures full expansion for reliable working loads.
- Non bottom-bearing, may be used in hole depth exceeding anchor length.
- Supplied complete with nut and washer.
- Can be installed through the work fixture, eliminating hole spotting.
- Inspectable torque values, indicating proper installation.
- Heavy duty pull-out and shear capacities.

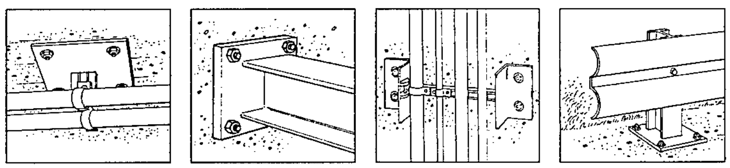
MODELS/VARIATIONS

Zinc-plated Carbon Steel—standard anchor for all structural and in-plant uses. Zinc-plated in accordance with Federal specification ASTM B633-85, SC1, Type III.

Galvanized Steel—provides protection from mildly humid, corrosive or brine atmospheres. Outdoor applications include fencing, gates, handrails, docks, conveyors, highway guard rails, signs, lighting and safety devices. Galvanized in accordance with ASTM A153 Class C. (Nuts and washers are also hot dipped galvanized.)

Stainless Steel—for protection in humid, highly corrosive and acidic environments. Used extensively in architecture to mount aluminum and stainless steel window frames and curtain walls. Bolt body 302HQ, 303, or 316 stainless steel. Type 302HQ stainless steel exhibits the same corrosion resistance as Type 304 stainless. It meets ASTM A276 and A479 specifications.

APPLICATIONS



• Structural supports to concrete • Tilt-up construction • Pipe hanging and machinery mounts • Highway rails, posts, and guard apparatus • Transportation and bridge construction • Fastening for electrical, HVAC, plumbing systems to concrete • Metal door and window frames

APPROVALS/LISTINGS

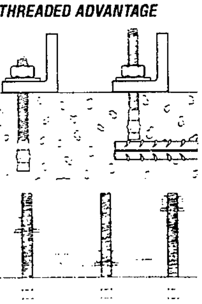
Meets or exceeds U.S. Government G.S.A. Specification FF-S-325 Group II, Type 4, Class I.

- UL Underwriters Laboratories.
- FM Factory Mutual.
- ICBO Evaluation Service, Inc. Report #1372.
- City of Los Angeles, Report #RR2748.
- Metro Dade County Florida.
- SBCCI Compliance Report #9368.
- California State Fire Marshal.

FULLY-THREADED ADVANTAGE

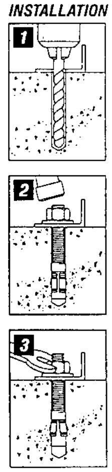
Trubolt's fully-threaded feature eliminates subsurface obstruction problems

Fully-threaded design accommodates various material thicknesses at the same embedment. One anchor length saves installation time and money



4

INSTALLATION STEPS



1.
Using a bit whose diameter equals the anchor diameter, drill hole to any depth exceeding minimum embedment. Clean hole.

2.
Assemble anchor with nut and washer so that the top of the nut is flush with the top of the anchor. Drive anchor through material to be fastened so that nut and washer is flush with surface of material.

3.
Expand anchor by tightening nut 3 to 5 turns, or to the specified torque requirement. (see selection chart)

See Installation Cautions on Back Page.

SELECTION CHART

Carbon Steel		Galvanized Steel		302HQ/303** Stainless Steel		316 Stainless Steel		Anchor Diameter & Drill Bit Size/ Threads Per Inch	A Overall Length	B Max. Thickness of Material to be Fastened	D Min. Embed-ment in Concrete	Instal-lation Torque (Ft. Lbs.)
Catalog Number	C Thread Length	Catalog Number	C Thread Length	Catalog Number	C Thread Length	Catalog Number	C Thread Length					
WS-1416* WS-1422* WS-1432*	3/4" 1-1/4" 2-1/4"			WW-1416* WW-1422* WW-1432*	3/4" 1-1/4" 2-1/4"	SWW-1416 SWW-1422	3/4" 3/4"	1/4"/20	1-3/4" 2-1/4" 3-1/4"	3/8" 7/8" 1-7/8"	1-1/8"	8
♦•WS-3822* ♦•WS-3826* ♦•WS-3830* ♦•WS-3836* ♦•WS-3850*	1-1/8" 1-5/8" 1-7/8" 2-5/8" 2-1/2"			♦•WW-3822* ♦•WW-3826* ♦•WW-3830* ♦•WW-3836* ♦•WW-3850*	1-1/8" 1-5/8" 1-7/8" 2-5/8" 2-1/2"	♦•SWW-3826 ♦•SWW-3830 ♦•SWW-3836	1-1/8" 1-1/8" 1-1/8"	3/8"/16	2-1/4" 2-3/4" 3" 3-3/4" 5"	3/8" 7/8" 1-1/8" 1-7/8" 3-1/8"	1-1/2"	25
♦•WS-1226* ♦•WS-1236* ♦•WS-1242* ♦•WS-1254* ♦•WS-1270*	1-1/4" 2-1/4" 2-3/4" 3" 4-1/2"	♦•WS-1226G* ♦•WS-1242G* ♦•WS-1254G* ♦•WS-1270G*	1-1/4" 2-3/4" 3" 4-1/2"	♦•WW-1226* ♦•WW-1236* ♦•WW-1242* ♦•WW-1254* ♦•WW-1270*	1-1/4" 2-1/4" 2-3/4" 3" 4-1/2"	♦•SWW-1226 ♦•SWW-1236 ♦•SWW-1242 ♦•SWW-1254	1-5/16" 1-5/16" 1-5/16" 1-5/16"	1/2"/13	2-3/4" 3-3/4" 4-1/4" 5-1/2" 7"	1/8" 1" 1-1/2" 2-3/4" 4-1/4"	2-1/4"	55
♦•WS-5834* ♦•WS-5842* ♦•WS-5850* ♦•WS-5860* ♦•WS-5870* ♦•WS-5884 ♦•WS-58100	1-3/4" 2-1/2" 3-1/4" 3-1/2" 4-1/2" 1-3/4" 1-3/4"	♦•WS-5834G* ♦•WS-5860G*	1-3/4" 3-1/2"	♦•WW-5834* ♦•WW-5850* ♦•WW-5860* ♦•WW-5870* ♦•WW-5884	1-3/4" 3-1/4" 3-1/2" 4-1/2" 1-3/4"	♦•SWW-5850 ♦•SWW-5884	1-3/4" 1-3/4"	5/8"/11	3-1/2" 4-1/4" 5" 6" 7" 8-1/2" 10"	1/8" 7/8" 1-5/8" 2-5/8" 3-5/8" 5-1/8" 6-5/8"	2-3/4"	90
♦•WS-3442* ♦•WS-3446* ♦•WS-3454* ♦•WS-3462* ♦•WS-3470* ♦•WS-3484 ♦•WS-34100 ♦•WS-34120	1-3/4" 2-1/4" 3" 3-3/4" 4-1/2" 1-3/4" 1-3/4" 1-3/4"	♦•WS-3446G* ♦•WS-3454G* ♦•WS-3484G	2-1/4" 3" 1-3/4"	♦•WW-3446* ♦•WW-3454* ♦•WW-3470* ♦•WW-3484 ♦•WW-34100	2-1/4" 3" 4-1/2" 1-3/4" 1-3/4"	♦•SWW-3446 ♦•SWW-3454	1-3/4" 1-3/4"	3/4"/10	4-1/4" 4-3/4" 5-1/2" 6-1/4" 7" 8-1/2" 10" 12"	1/4" 3/4" 1-1/2" 2-1/4" 3" 4-1/2" 6" 8"	3-1/4"	175
WS-7860 WS-7880 WS-78100	2-1/2" 2-1/2" 2-1/2"			WW-7880	2-1/2"			7/8"/9	6" 8" 10"	1-3/8" 3-3/8" 5-3/8"	3-3/4"	250
†WS-10060 †WS-10090 †WS-10J120	2-1/2" 2-1/2" 2-1/2"	†WS-10090G	2-1/2"	WW-10060 WW-10090	2-1/2" 2-1/2"			1"/8	6" 9" 12"	1/2" 3-1/2" 6-1/2"	4-1/2"	300
S-12590 S-125120	3-1/2" 3-1/2"							1-1/4"/7	9" 12"	2-1/4" 5-1/4"	5-1/2"	500
Tie Wire TWS-1400	N/A							1/4"	2-3/16"	Eye Dia. 9/32"	1-1/8"	N/A

**Fully Threaded*

PERFORMANCE CHARTS

Carbon Steel

Anchor Size	Embed-ment in Concrete	4000PSI[1] Ultimate Pullout[2] Lbs.	4000PSI[1] Ultimate Shear[2] Lus.
1/4"	1-1/8" 1-15/16" 2-3/4"	1559 2999 3051	1828 1910 1991
3/8"	1-1/2" 3" 4-1/2"	3219 5678 6935	4029 4305 4581
1/2"	2-1/4" 4-1/8" 6"	5384 7333 9003	6900 7449 7998
5/8"	2-3/4" 5-1/8" 7-1/2"	8000 10178 12453	12478 13285 14092
3/4"	3-1/4" 6-5/8" 10"	9921 16489 19953	18128 18585 19042
7/8"	3-3/4" 6-1/4" 8-3/4"	13672 20029 20707	25122 25122 25122
"	4-1/2" 7-3/8" 10-1/4"	20871 30610 37820	28431 29763 31094
1-1/4"	5-1/2" 8" 10-1/2"	27166 53261 60417	44385 46776 48689
Tie Wire	1-1/8"	1559	N/A

Stainless Steel

Anchor Size	Embed-ment in Concrete	4000PSI[1] Ultimate Pullout[2] Lbs.	4000PSI[1] Ultimate Shear[2] Lbs.
1/4"	1-1/8" 1-15/16" 2-3/4"	1869 3084 3102	2354 2375 2395
3/8"	1-1/2" 3" 4-1/2"	3145 5661 6396	4338 5012 5686
1/2"	2-1/4" 4-1/8" 6"	6032 8593 9974	9542 9773 10003
5/8"	2-3/4" 5-1/8" 7-1/2"	7646 11897 12791	13339 14227 15115
3/4"	3-1/4" 6-3/8" 9"	10069 16027 16839	18773 21795 24153
7/8"	3-3/4" 6-1/4" 8-3/4"	15295 18687 25311	26198 28826 30018
1"	4-1/2" 7-3/8" 10-1/4"	18988 20764 22755	33408 36260 39111

[1] Performance data also available for concrete strengths from 2500 to 5500 PSI, and lightweight aggregate concrete from 4000 to 6000 PSI

†Carbon steel anchor sizes through 7/8" in diameter have stainless steel expansion clips. Larger diameter carbon steel and galvanized anchors have carbon steel expansion clips. All size stainless steel anchors have stainless steel expansion clips. †Denotes carbon steel clip.

[2] Ultimate load capacity in 4,000 PSI stone aggregate concrete. Ultimate pullout and shear loads are indicated for the depth of embedment in concrete shown in the "Embedment in Concrete" column. Based on Independent Testing Laboratory tests.

1-1/4" diameter carbon steel anchors were tested at a depth of 10-1/2" for tensile capacities and 10" for shear.

1" diameter stainless steel anchors were tested at a depth of 10-1/2" for tensile capacities and 10-1/4" for shear.

Safe working loads for single installations under static loading should not exceed 25% of the ultimate load capacity. For information on other conditons, contact your nearest factory representative.

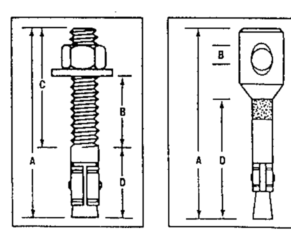
For load capacities in structural lightweight aggregate concrete, refer to ICBO Report =1372 or contact Technical Service Department.

For extreme low temperature applications use stainless steel anchors.

NOTE: Capacities shown in Selection Chart are based on most recent testing perfomed in compliance with ASTM E-488 and ICBO Research Committee Standards for Testing Expansion Anchors in Concrete.

♦Indicates FM Approval • Indicates UL Listing.

***"WW" anchor body material may be Type 303 or Type 302HO according to metal forming efficiency. Type 302HO meets corrosion resistant properties of Type 303 and 304*



5

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13. ABSTRACT *(Maximum 200 words)*

A number of dams owned and operated by the Corps of Engineers exhibit significant water leakage through cracked or deteriorated concrete and defective joints. Applications of geomembranes in Europe have been so successful in arresting concrete deterioration and controlling leakage that these systems are considered competitive with other repair alternatives. However, the geomembranes were typically installed in a dry environment by dewatering the structure on which the system is to be installed. Dewatering can be extremely expensive and in many cases may not be possible because of project constraints; therefore, a procedure for underwater installation of geomembrane repair systems was developed.

In Phase I, a conceptual design for the underwater repair system was developed. The constructibility of the design was demonstrated in Phase II through successful underwater installation of the system on a simulated concrete structure. The underwater demonstration of the innovative geomembrane repair system is described herein. Compared to dewatering of a structure for repair, a geomembrane system that can be installed underwater minimizes the impact of the repair on project operations such as hydropower generation and recreation. Also, the underwater repair system eliminates the potentially adverse environmental impacts associated with dewatering of many structures.

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